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DIATHERMY

STAFFORD L. OSBORNE, D.P.E., M.S., PH.D.



## DIATHERMY

The Use of High Frequency Currents

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The Use of High Frequency  
Currents

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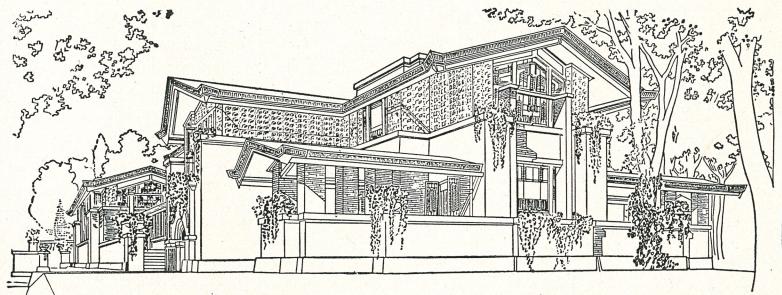
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## PREFACE

THIS monograph has been written solely for those interested in the subject of diathermy. The author does not pretend to present a complete treatise on diathermy but rather some of the more salient features of the subject. It is written with the hope it will be useful to the medical student and physical therapist, as well as the general practitioner.

It is also hoped it will be the means of stimulating the reader to further study.

Chicago, Illinois

STAFFORD L. OSBORNE

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## DIATHERMY

The Use of High Frequency Currents

# I

## INTRODUCTION

**I**N 1881 D'Arsonval began a study of the physiologic effects of alternating current on muscles and nerves. After studying the effects of a single wave he began to use waves which developed periodically. When the current frequency reached 20 to 30 cycles per second he found the human muscle did not respond to each individual alternation of the current but responded with a fused tetanic contraction that was sustained during the flow of the current through the muscle. D'Arsonval discovered that up to 2,500 to 5,000 cycles per second excitation increased with increasing frequency. With frequencies above 2,500 to 5,000 cycles per second excitation decreased as the frequency increased. His apparatus, however, was limited to a frequency of 10,000 cycles per second. Therefore, in December, 1890, he discarded his own apparatus and substituted that of Hertz which gave several million excitations per second.

Because of the limited output of this oscillator D'Arsonval replaced it in 1891 with one designed after the generator of Elihu Thomson. Now D'Arsonval discovered that with frequencies above 10,000 cycles per second all neuromuscular responses disappeared; and, that a feeling of warmth replaced neuromuscular response. Thus he demonstrated that alternating current beyond a frequency of 10,000 cycles per second when absorbed by human tissues was transformed into heat. He also showed that these currents could be passed through the human body without harmful effects and with intensities that at lower frequencies would be lethal. In a note to the Academy of Sciences, March 20, 1893, D'Arsonval states, "I have been able to pass thru my arms a current of 3 amperes (3,000 milliamperes) without experiencing any other effect than a lively sensation of warmth limiting the intensity at the level of the wrists." Thus it was D'Arsonval who from 1889 to 1892 discovered the fundamental facts which

serve as a basis for the entire therapy of high frequency current. In addition, D'Arsonval continued to study the physiologic effects of these high frequency currents and made many outstanding contributions.

Reviewing his own experiments D'Arsonval concluded that high frequency currents penetrated profoundly into the body instead of accumulating on the surface. The correct explanation of the action of the current, however, was first made by von Zeynek in 1899. He stated that the heat was produced in tissues due to the resistance the current experienced in passing through them. In 1907 Nagelschmidt used the term "diathermy" to indicate the "heating through" of the current. But diathermy proper did not enter into medical practise until about 1910, a few years after the publications of von Zeynek, Bernd, Doyen, and Nagelschmidt. Progress was rapid. Treatment was given by means of a spark gap generator. The frequency of current oscillation ranged from approximately 400,000 to 4,000,000 cycles per second (750 to 75 meters in wavelength).

Development of the vacuum tube oscillator made further progress possible as well as a dramatic change in the application of this therapy. Higher frequencies were made available ranging from 12,000,000 to 50,000,000 cycles per second, or 25 to 6 meters in wavelength. This new method of application has been termed "Short Wave Diathermy." The term "Conventional Diathermy" has been coined to designate the original spark gap type of diathermy.

The next significant change occurred when perfection of the magnetron tube made possible the generation of extremely high frequency oscillations. These extremely high frequency oscillations are termed "Microwaves." One generator known as the "Microtherm" has been designed for medical diathermy. The "Microtherm" uses a magnetron tube generating a high frequency current of approximately 2,450 megacycles—practically two and one-half billion cycles per second—or a wavelength of 12.2 centimeters. Thus, there is a wide gap between short wave diathermy—3 meters—and microwaves of 12.5 centimeters. The

use of short wave diathermy and microwaves has greatly influenced the method of diathermy application.

From this brief discussion it can be seen that diathermy (deep tissue heating) has passed through three distinct stages of development. Each stage has left its marked imprint on both technic and nomenclature. Perhaps it is unfortunate that the various terms have been applied because the nomenclature has become somewhat cumbersome and unwieldy. The following classification is the one most usually accepted:

#### I. CONVENTIONAL DIATHERMY

*Generator*—Spark gap oscillator

*Frequency range*—400 to 3,000 kilocycles per second

*Current form*—Damped wave

*Application*—Metal electrodes applied directly in contact with skin.

#### II. SHORT WAVE DIATHERMY

*Generator*—Vacuum tube oscillator

*Frequency range*—10 to 30 megacycles per second—wavelength 30 to 10 meters

*Current form*—Undamped wave

*Application*—Insulated metal electrodes applied to tissues.

##### A. ULTRA SHORT WAVE DIATHERMY

*Generator*—Vacuum tube oscillator

*Frequency range*—30 to 100 megacycles per second—wavelength 10 to 3 meters

*Current form*—Undamped wave

*Application*—Insulated metal electrodes applied to tissues.

#### III. MICROWAVE DIATHERMY

*Generator*—Magnetron tube and/or vacuum tube oscillator

*Frequency range*—300 to 2,450 megacycles—1 meter to 12.5 cm. wavelength

*Current form*—Undamped wave

*Application*—Radiation reflected to patient from parabolic reflector.

## II

## RADIO INTERFERENCE CAUSED BY SHORT WAVE DIATHERMY APPARATUS\*

THAT part of the radio spectrum at first used by short wave diathermy was generally outside the region usually employed for communications. Guided by the early clinical investigators, the manufacturers of short wave diathermy apparatus selected channels ranging from 30 to 6 meters for therapeutic purposes. Each channel had its vociferous advocates. However, time and effort in research eventually established the therapeutic value of this physical agent. After several years of careful investigation the Council on Physical Medicine of the American Medical Association concluded that short wave diathermy was merely another means of applying heat to the patient. Furthermore, they believed that all wavelengths between 30 and 5 meters had equal therapeutic value.

During this period radio communications was making phenomenal progress. It was not long before the amateur radio operators were using these channels for communications and observed interference originating from diathermy equipment. As radio communications expanded, more channels were needed for services such as ship to shore, airplanes to ground, police station to ground, walkie-talkies and finally television. Diathermy interfered with television occasionally, to such an extent that the picture in the television receiver was indistinguishable.

A little more than twelve years ago the radio communication agencies requested the Federal Communications Commission to formulate regulations to control man-made interference caused by diathermy equipment. It soon became apparent there was no simple solution. Screened rooms were suggested but ruled out as too expensive and cumbersome.

\* Council on Physical Medicine: Federal Communications Commission announces its regulations for short wave diathermy apparatus. *J.A.M.A.*, 135:31, (September 6) 1947.

Probably the greatest problem to radio communication is in the congested areas. For instance, diathermy apparatus which is not controlled might be used in a physician's office located in an apartment building. Without knowing it the physician might cause considerable annoyance to other residents of the building when using their radio or television sets. Police work might be seriously jeopardized by diathermy interference when on an important call. At the present time this is one of the most frequent causes of complaint. Diathermy apparatus may be housed in a wooden building and the receivers on the police squad cars cruising in the streets will pick up the radio signal having the greatest field strength when frequency modulation receivers are employed. When amplitude modulation receivers are used, serious interference will result even though the field strength of the signal radiated by the diathermy equipment is as low as one-twentieth of the field strength of the police radio signal.

In 1939 the Federal Communications Commission called a meeting of the interested bodies in New York to discuss the problem. After Herculean efforts on the part of the Radio Technical Planning Board of the radio industry, the Federal Communications Commission and the Council on Physical Medicine of the American Medical Association, the Federal Communications Commission released Public Notice Number 7732 on May 9th, 1947.

In this document the Federal Communications Commission assigned three frequencies in harmonic progression, for medical diathermy and industrial heating as follows:

Assigned Band	Center Frequency of Channel	Tolerance from Center Frequency
13.533-13.566 Mc. or 21 meters	13.560 Mc.	6.78 Kc.
29.960-27.280 Mc. or 11 meters	27.120 Mc.	160.00 Kc.
40.660-40.700 Mc. or 7.5 meters	40.680 Mc.	20.00 Kc.

Mc. = megacycles per second

Kc. kilocycles per second

Harmonic and spurious radiations on frequencies other than those specified shall be suppressed, so that radiation will not

exceed a strength of 25 microvolts per meter at a distance of 1,000 feet or more from the diathermy equipment causing such radiation.

Other channels assigned for medical, industrial, and scientific use are 915, 2,450 (12.2 cm.), 5,850, 16,600 and 18,000 megacycles. A frequency of 6 megacycles is promised for use in the future.

At present the commission has not found it necessary to make any rules applicable to surgical diathermy.

A physician owning and operating a diathermy apparatus manufactured prior to July 1, 1947 may continue to operate for a period of five years, provided the equipment does not interfere with authorized radio services. If interference is reported, the physician is responsible for eliminating the disturbance to radio communications. This may be accomplished in some instances by readjusting the existing diathermy appliance. If no means can be provided to eliminate the interference, then the physician becomes subject to the new rules and regulations. That is to say, he must screen the apparatus or acquire frequency controlled equipment.

The commission ruled that all diathermy equipment manufactured in the future shall meet these regulations if the equipment is to be used without a license. Using a type-approved apparatus, a physician need not obtain an operating license. If a physician is using existing equipment operating on a frequency not assigned, shielding must be employed and certification obtained. This rule refers to apparatus that was purchased prior to July 1, 1947.

There are generally two methods of operating diathermy equipment in compliance with these rules for equipment manufactured after July 1, 1947. The first method is to operate within assigned frequency bands using equipment either "type-approved" or certified by a competent engineer in accordance with the applicable sections of the rules. The second method is to operate on any frequency provided the equipment is operated in a shielded room with a filtered power supply and all radiation

on any frequency limited to 15 microvolts per meter at a distance of 1,000 feet or more from the diathermy equipment. Operation in this manner also requires certification by a competent engineer.

Apparatus is being manufactured now to meet the Federal Communications Commission requirements. It is quite evident that the greatest tolerance is with the 11 meter wavelength and consequently many manufacturers are using this wavelength because it is easier to keep within the required wave band width, although it may not be in the best interest of the physician.

Manufacturers are building crystal controlled generators to maintain the desired frequency band within proper tolerance limits. While this method is more expensive initially, the user of crystal controlled apparatus is likely to have less trouble with frequency drift. Service troubles will also be less costly over a period of time. The most efficient method for diathermy is the induction method and the best wavelength for this is approximately 21 meters. To keep within the specified tolerance at this wavelength, crystal controlled frequency is necessary.

Some manufacturers use a new tube—the condenser vacuum tube—but there have been reports that frequency drifts are not infrequent with such apparatus. Replacement of such tubes is expensive and the life of such tubes at present is not too well known. The tube may also require excessive servicing. Some generators use a built-in receiver which automatically turns off the unit when frequency drifts occur beyond the prescribed channel. Movement of the patient may cause this drift and it would be necessary to turn the machine on again when this happens. It would seem wise at present to use the crystal controlled machine.

## III

## APPROVED APPARATUS

THE INVESTIGATION of physical therapy apparatus submitted voluntarily by the manufacturer for "Approval" by the Council on Physical Medicine and Rehabilitation of the American Medical Association is one of the Council's most useful and important functions. By this means the Council endeavors to protect the medical profession and the public interest against fraud, misrepresentation, inefficiency, undesirable secrecy, and objectionable advertising in connection with apparatus and methods employed in the administration of physical medicine. All approved equipment is listed in an official pamphlet entitled "Apparatus Accepted" and published yearly by the Council. The pamphlet is free and can be secured from the secretary of the Council on request. Advantage should be taken of this service for the booklet contains a wealth of valuable information.

Therefore, before buying diathermy equipment—or any other physical therapy apparatus—consideration should be confined only to that type of apparatus which has been approved by the Council on Physical Medicine and Rehabilitation.

Before a diathermy apparatus can be considered for approval by the Council the manufacturer must provide the following information:

1. Evidence to substantiate the therapeutic claims made for diathermy apparatus.
2. Data to substantiate the claims made for the heating efficacy of the unit.

Two methods are recommended by the Council on Physical Medicine and Rehabilitation for substantiating the heating efficacy of diathermy apparatus:

1. Temperature readings in the living muscle tissue of the anterior aspect of the human thigh, or,
2. Phantom loads:

(a) Lamps; and,

(b) Calorimeter containing isotonic solution of sodium chloride.

The Council will accept evidence procured by either 1 or 2 or by both.

In case of controversy or question of the validity of the data obtained by the "phantom method," the "thigh method" shall be used to establish the heating ability of the diathermy apparatus under test.

3. Evidence that radio interference has been reduced to a minimum. To be eligible for acceptance, the diathermy apparatus as it is supplied to the trade must be submitted to the Chief Engineer, Federal Communications Commission, Washington 25, D.C., for testing and "type approval" received.
4. Manufacturers shall be required to supply a copy of the Listing Report of the Underwriters' Laboratories, Inc., covering the apparatus in question.
5. The power output and input shall be given. The details of measurement must be described in such a manner as to enable the Council to repeat the experiment.
6. Diagram of the circuit.
7. A statement giving the facilities provided by the manufacturer or dealer to service diathermy apparatus. A list of service depots shall be given.
8. Twenty copies of each piece of current advertising matter.

In addition, the Council will give each diathermy apparatus submitted a practical test in an acceptable clinic over a reasonable period of time.

## IV

## HIGH FREQUENCY CURRENTS

### TECHNIC OF LOCAL APPLICATION

BY LOCAL application is meant the local or regional application of high frequency electric energy for the purpose of generating heat in a local or regional part of the body, in contradistinction to general application for the purpose of elevating the temperature of the entire body.

The local application of high frequency currents and fields may be for either medical or surgical effects, the effect obtained depending upon the energy input per unit volume of tissue per unit time. An application which does not produce destruction of tissue cells or impairment of their function is termed *Medical Diathermy*; whereas, if the application is such that destruction is obtained, it is termed *Surgical Diathermy*.

For either application, damped or undamped waves may be employed. The application of the spark gap oscillator, generating a succession of damped waves, for either medical or surgical purposes, is known as *Conventional Diathermy*. The application of high frequency currents generated by a vacuum tube oscillator is referred to as *Short Wave Diathermy*. The application of high frequency currents generated by a magnetron tube is designated *Microwave Diathermy*. Conventional diathermy is being rapidly replaced by short wave diathermy. However, conventional diathermy is still being used by some. For that reason, the technic to be followed in administering treatment by this method has been included in the following discussion.

#### GENERAL PRINCIPLES OF TECHNIC

1. Diathermy should never be applied over areas of the body where injury has damaged the sensory nerves. Over such areas heat sensation may be entirely absent, or the patient may not be able to discriminate readily variations in heat intensity. The

ability to sense heat must be unimpaired in patients to whom diathermy is to be administered.

2. During the first treatment it is advisable to keep well below the patient's maximum heat tolerance. In this way the confidence of the patient is secured, and, in addition, any unusual reaction to heat may be noted.

3. The patient should be informed that no sensation other than that of a comfortable degree of heat should be experienced. If other effects than a comfortable diffused heating are present, such as a so-called "hot spot," a minute prickling sensation, or an uncomfortable heat, the patient must be warned to notify the operator immediately.

4. The only safe guide for dosage is the patient's tolerance. The tolerance to heat must never be exceeded.

5. Patients must be warned against disturbing the electrodes in any manner whatsoever, once they are applied.

6. While it is not necessary for the operator to be with the patient throughout the entire treatment, it is essential that the patient should be under supervision. In some instances, patients are provided with a switch-cord, permitting them to terminate the treatment if too much heat is felt beneath the electrode or other untoward effects are experienced. Such a device should not be necessary, however, if proper technic is followed.

7. The generator should be placed beyond the reach of the patient, and if not, he should be warned against touching any part of the apparatus while undergoing treatment. He should also be warned against making contact with metal partitions, wall switches, and all other grounded objects and current-carrying conductors.

8. Metal beds or metal treatment tables should not be used for patients during diathermy application. Should their use be unavoidable, special precautions must be taken to prevent contact of either patient or apparatus with the metal. Treatment tables for such applications should be of wood.

9. Before starting treatment, all controls should be at zero.

10. After the generator has been energized, the intensity con-

trol, which determines the rate of energy input into the tissues, should be gradually increased to obtain the desired intensity. Only when it is impossible to obtain the desired current by means of the intensity control, should the spark-gap distance be increased; this applies only of course in the case of a conventional diathermy apparatus.

11. Increase the current intensity gradually when using the vacuum tube as well as the spark-gap oscillator, reaching the desired maximum current intensity in approximately five minutes.

12. At the termination of the treatment, all controls should be brought to zero before turning off the main switch. In case of an emergency, however, the main switch should be turned off without hesitation.

### CONVENTIONAL DIATHERMY

There are three general methods of application: direct, indirect, and autocondensation.

#### DIRECT

**Electrodes.** The electrodes for conventional diathermy applications may be either of bare metal applied directly over the skin, or of some absorbent material such as cellucotton, canton flannel, or orthopedic felt, which is made conductive by saturating in twenty per cent sodium chloride solution; or the electrode may be a vessel containing a conductive solution into which the part is immersed, thus serving as one of the electrodes. In our opinion, the electrodes of choice are those of metal applied directly to the skin. We shall, therefore, confine our technic to this type of electrode. However, the absorbent type of electrode may be preferred by some. If such electrodes are used, they are applied in the same manner as the absorbent electrodes for direct current applications.

Metal electrodes are made of a metal alloy and must be quite pliable. We have found the thickness of 0.016 inch (25 gauge) to be quite satisfactory. This is sometimes known as medium foil, and is usually sold by the pound. This foil can be readily

cut into any desired shape. It is advisable to prepare a complete set of electrodes such as that illustrated in Figure 1.

The metal electrode should be so cut that all edges are clean and smooth and not left jagged. All corners must be rounded

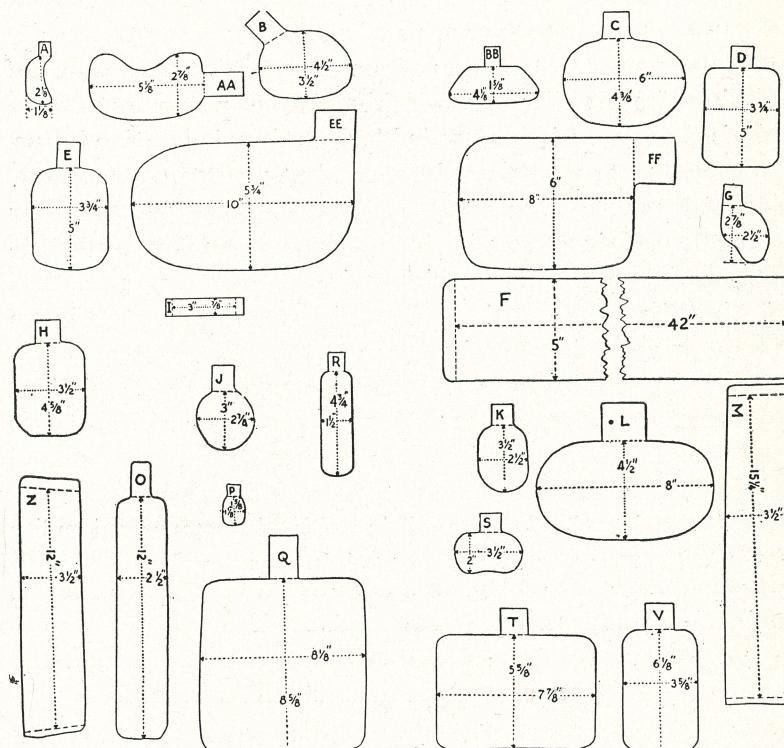


FIGURE 1. Suggested set of electrodes for conventional diathermy application.

and not square. The edges should be rounded to minimize concentration of current at the edge of the electrode. When cutting the electrode, leave a projecting tab for the purpose of attaching the patient's conducting cord. By means of a 12-inch roller, approximately one inch in diameter, such as a metal autocondensation handle or a 12-inch length of a broom handle, the electrode, prior to every application, should be rolled smooth and entirely free of rucks. Creases in the electrode must be eliminated.

When the electrode needs shaping to conform to the contour of the part under treatment, the moulding should be done with a minimum of electrode handling. Once the electrode is finally placed in position, it should be held at its center lightly in contact with the skin. It should be free from pressure at the edges until held in position by means of a sandbag or bandage. It is very important that the edges of the electrode do not press into the skin. The pressing into the skin of a sharp edge of an electrode is the cause of the so-called "edge effects" and edge burns. It is necessary to secure good contact but uneven contact must be carefully avoided, particularly at the edges. When bandages are used to retain electrodes in position, they must not be applied too tightly. Otherwise, circulation might be retarded, thus defeating the purpose of administering treatment, namely, to promote an active hyperemia.

Electrodes should be warmed before applying to the patient to avoid any disagreeable sensation from contact with the cold metal. Some operators prefer to apply a conductive jelly, such as K-Y Jelly, on electrodes made of metal foil to minimize electrode discomfort, but in the clinic at Northwestern University it has not been our custom to use such lubricants. However, with certain types of spark-gap oscillators it may be desirable to use some conductive compound on the electrodes.

With the metal mesh electrode, a conductive compound must always be used. Soap lather has been widely used for this purpose, but such a medium is an extremely poor conductor and should not be employed.

**Conducting Cords.** Such cords are used to conduct the current from the high frequency apparatus to the electrodes. To prevent the weight of the cord from pulling on the electrode and eventually displacing it, the weight of the cord should be supported by tucking a section of it under the mattress or under the pillow of the patient's treatment table, or by placing a sandbag over it to hold the cord in such a manner as to prevent any pull on the electrode.

## SPECIFIC TECHNICS OF APPLICATION

**Double Plate Through and Through, or Transverse Method.**

The part of the body to be treated is sandwiched directly between two electrodes (Figure 2). The two electrodes may be equal in size, or one may be larger than the other.

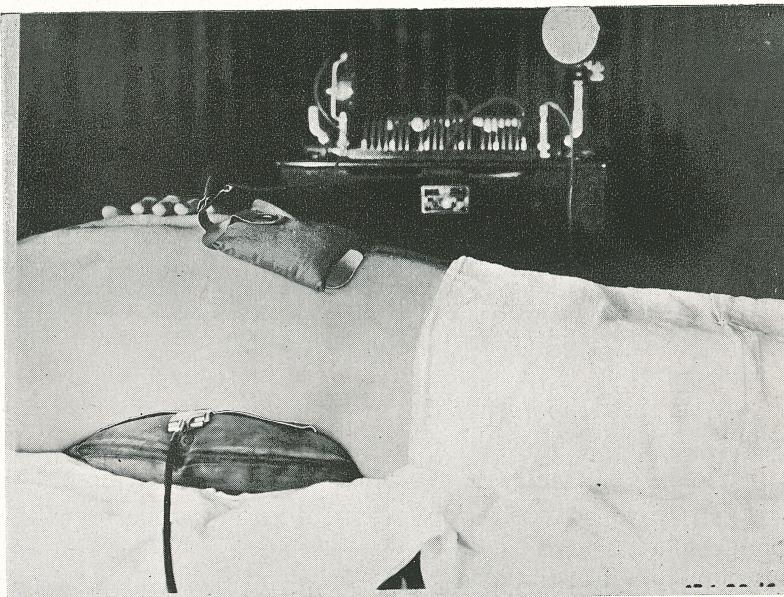


FIGURE 2. Double Plate or Transverse Method of Application.

Electrodes having the same area are employed in an attempt to produce heat to the same degree throughout all of the tissues sandwiched between the two electrodes. However, because of the heterogeneity of tissue from an electrical viewpoint, and because of the spreading out of the current flow from electrode to electrode even in homogeneous tissue, a uniform rate of heat production per unit volume of the tissues between the electrodes cannot be achieved. Electrodes of equal area, however, assure equal current densities at both contact surfaces. Both electrodes, when of equal size, are considered active electrodes.

When it is desired to produce heat at a greater rate near one electrode than at the other, electrodes of unequal area are employed. The current density will be greatest beneath the smaller electrode. Consequently the rate of heat production will be greater near this electrode. Hence, if there is a difference in the areas of the two electrodes, heat will be felt primarily in the region of the smaller one. The greater the difference in area, the greater will be the relative heating in the region of the smaller electrode. The smaller electrode is therefore referred to as the active electrode, the larger electrode being referred to as the dispersive electrode.

When using the double-plate technic, it is important that the current path through the tissues sandwiched between the plates be shorter than the current path over the skin from the edge of one electrode to the edge of the other. Should the electrodes be so applied that the current path over the surface from edge to edge of opposing electrodes presents less resistance to the flow of current than the deeper tissues, an excessive portion of the total current will flow through this path with an inadequate flow of current through the remainder of the tissues. The result is an excessive concentration of current flow at the opposing edges of the electrodes with consequent marked discomfort and burning, commonly known as *edge effect*.

The opposing edges of the electrodes must be equidistant from each other in so far as is possible. If the edges are not equidistant, there will be a concentration of current and hence of heat production where the edges are closest together. It is important when treating a tapering part, such as a thigh, that the electrode be of such configuration and so applied that as near a uniform distribution of current as practicable be secured. To achieve uniform distribution of current through a tapering of conical volume such as a thigh, the opposing electrodes must of necessity be wedge-shaped in that their width at the smaller diameter of the thigh be less than their width at the larger diameter. Their relative widths should be such that when the

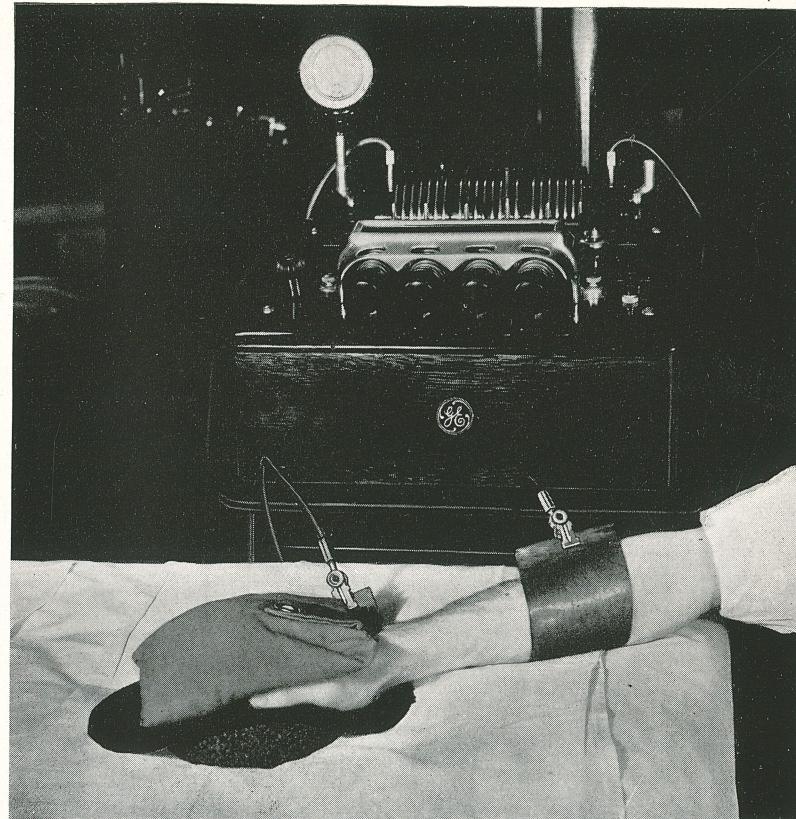


FIGURE 3. Plate and Cuff Method. Treatment of wrist.

electrodes are applied to the thigh their opposing edges are equidistant.

**Plate-and-Cuff or Longitudinal Method.** This technic is used principally for such joints as the wrist, hand, ankle, and foot (Figures 3 and 4). One electrode is a rectangular metal plate approximately 10 inches by eight inches. The actual size is determined by the size of the hand or the foot of the patient. If a joint such as an ankle is to be treated, the entire foot must be in contact with the metal plate. The other electrode consists of a metal cuff about three inches wide and of sufficient length to en-

circle completely the calf of the leg. When electrodes are properly applied, heat will be felt at the ankle joint and not in the region of either electrode.

**Double Cuff Method.** This method is used for the treatment of such joints as the elbow and knee. The cuffs are three inches wide, and of sufficient length to encircle completely the arm or leg and to permit clamping together about  $1\frac{1}{2}$  inches of the ends of the cuff. The ends are folded over once to secure and maintain adequate contact between cuff and skin surface. An electrode clip is clamped over the fold to secure the electrode and to provide an electrical connection.

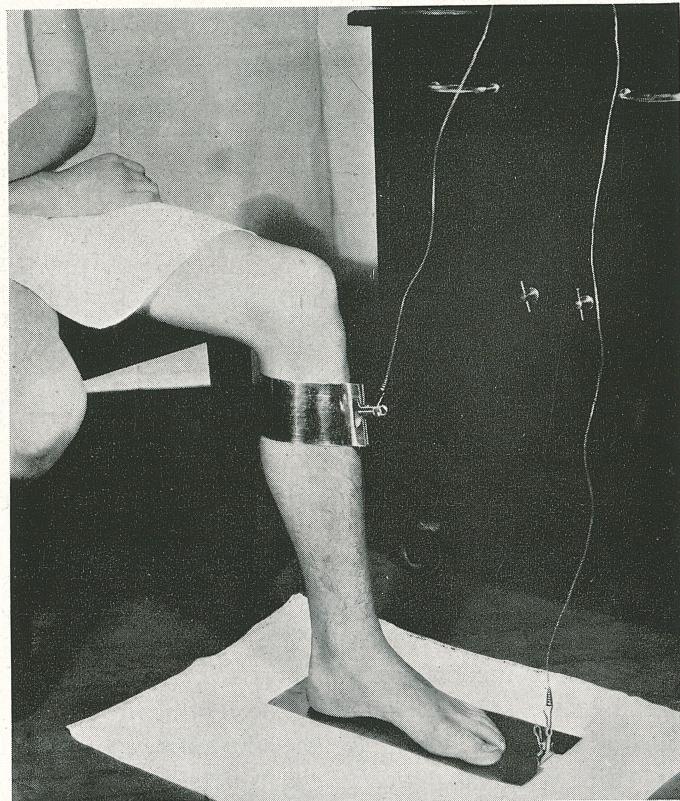


FIGURE 4. Plate and Cuff Method. Treatment of ankle.

The joint to be treated should be equidistant from the two cuffs which encircle the arm or leg. When the double cuff method is used, the arm or leg under treatment should be fully extended. If the joint is flexed, the current density will be greater through the tissues forming the shorter path, with conse-

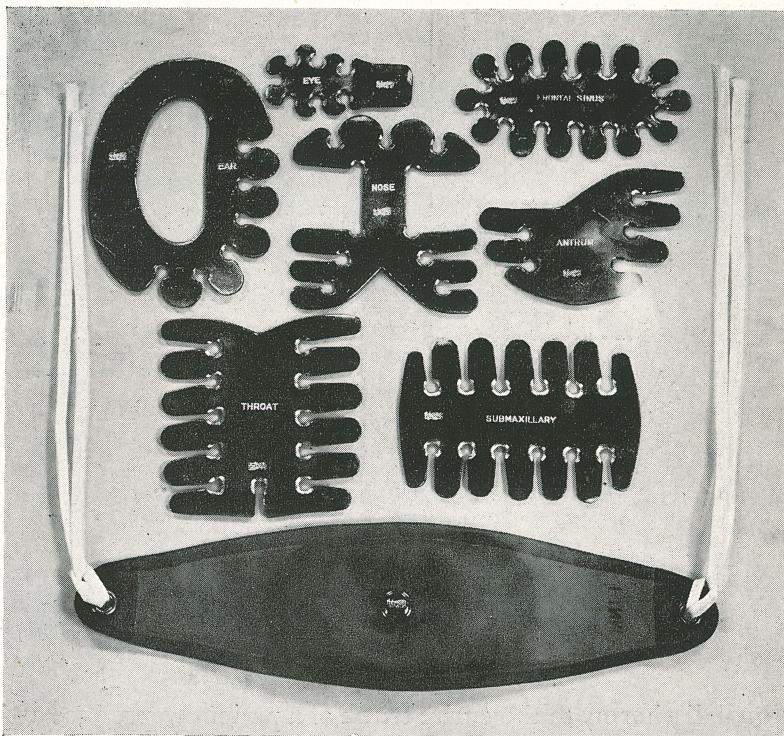


FIGURE 5. Novak fenestrated electrodes for the application of conventional diathermy to head and face.

quent excessive heating in those tissues. Cuffs should completely, and not partially, encircle the arm or leg. The cuffs should be placed as far apart as the anatomical configuration of the part to be treated will permit.

**Special Electrodes.** Fenestrated metal foil electrodes with a sinuated periphery were made for the application of conven-

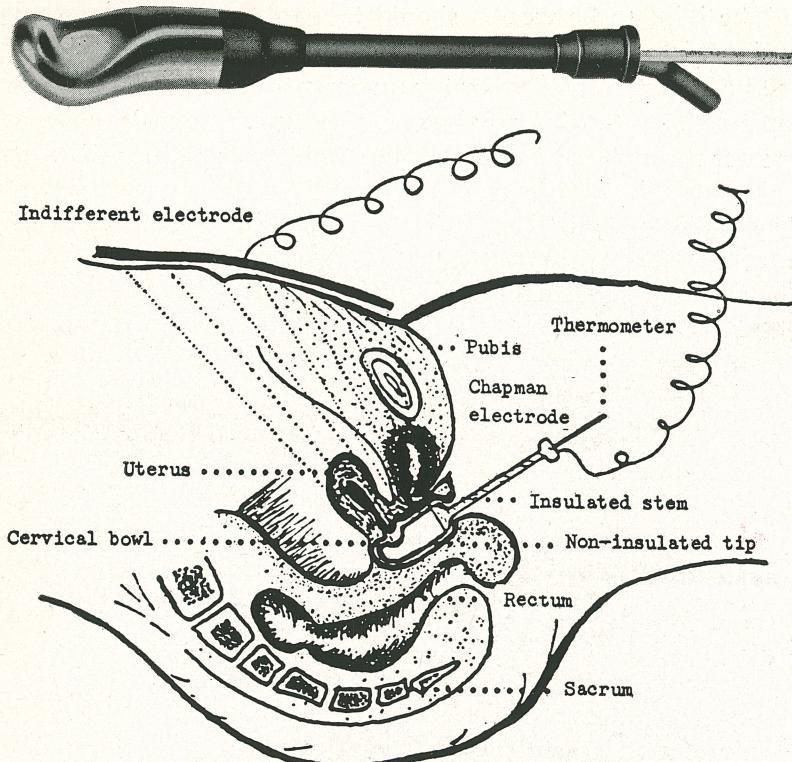


FIGURE 6a. Chapman Vaginal Electrode. Cross section of the female pelvis showing Chapman Electrode in position. (From Chapman: *Am. J. Phys. Therapy*, May, 1927.)

tional diathermy to the entire trunk of a patient to produce artificial fever. These were known as *Neymann Electrodes*. Modifications of these electrodes have been used for the application of diathermy to the head and face as well as to other parts where application of the ordinary foil electrode is difficult. Novak devised a set of electrodes of this type for applying diathermy to the region of the head and face. They are illustrated in Figure 5.

Various *orificial electrodes* have been devised for the application of diathermy directly to the vagina, cervix, rectum, and prostate (Figure 6). These electrodes are of metal and usually

plated with a non-corroding metal. Some of the electrodes are provided with a thermometer which measures the surface temperature of the tissues undergoing treatment. When using such electrodes, it must not be assumed that the temperature of the deeper tissues is the temperature indicated by the thermometer.

**Dosage.** By dosage is meant the total input of energy. The total input of energy into a given load having a constant effective resistance is determined by the current flow and the time that current flows. In administering diathermy it is therefore

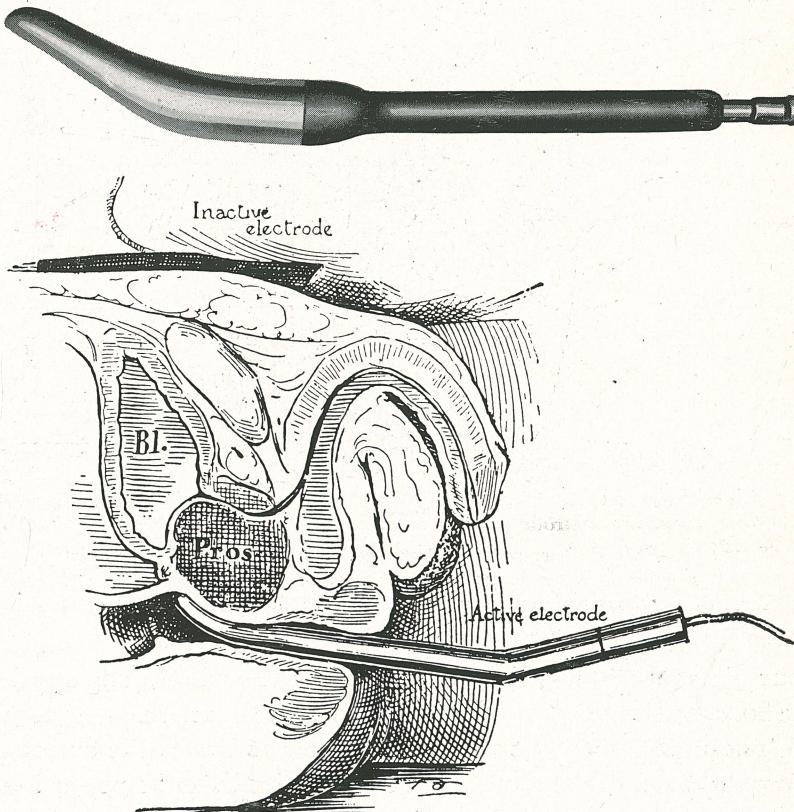


FIGURE 6b. Prostatic electrode. Cross section of the male pelvis illustrating the application of the prostatic electrode. (From CORBUS and O'CONNOR: *Diathermy in the Treatment of Genito-Urinary Diseases*. Courtesy Bruce Publishing Company.)

The duration of a treatment usually varies from 20 to 40 minutes. However, it is doubtful whether a treatment of such short duration is most effective therapeutically. The duration and the intensity of the treatment should be determined by the pathology it is desired to influence. For certain pathologies, short treatments given at definite intervals throughout the day may be indicated; while for other pathologies, long periods of low intensity treatment may be more effective.

**Specific Principles of Technic.** In the application of conventional diathermy, certain specific principles of technic should be carefully observed, in addition to the general principles governing the technical application of high frequency currents and fields which were discussed in the general introduction of this section. These specific principles are:

1. The skin should be examined for skin abrasions or pustular eruptions, and if present adhesive tape should be applied individually to each pustular eruption.
2. The electrodes should be applied according to the technic already described, and the proper milliammeter scale selected for the range of current to be used.
3. After the electrodes have been applied, the line-switch is closed and the spark gaps gradually opened. The spark gaps should be operated with minimum spacing. Too wide a gap will produce the so-called "faradic" sensation.
4. The milliamperage should always be increased slowly, the required intensity being reached in about five minutes.
5. When it is necessary to increase the current, do so by means of the intensity control or other controls that may be provided for that purpose. Do not open the spark gaps further, however, unless the other means of increasing the current flow are incapable of giving the desired current.
6. If dry metal electrodes give discomfort to certain individuals, the use of a good conducting compound is indicated.

#### INDIRECT

This method of treatment was developed because limitations

of generators made it impossible to treat certain regions of the body. Indirect diathermy produces merely superficial heating and counter-irritation. It is administered in one of two ways:

1. The patient is seated and holds an autocondensation metal handle, which is connected to one terminal of the machine. A so-called hand electrode is applied to the wrist of the operator and connected to the other machine terminal. An alternate tech-

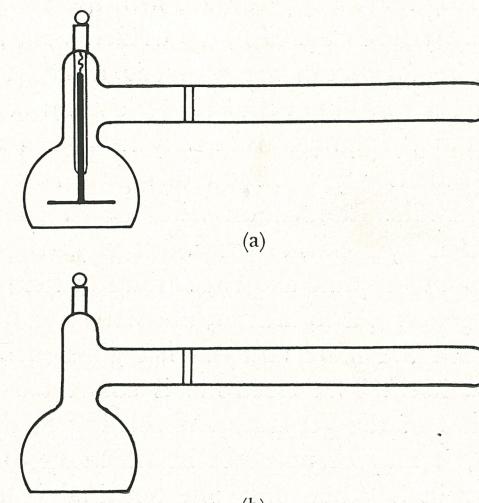


FIGURE 7. (a) Non-vacuum electrode. (b) Vacuum electrode.

nic is to have the patient lie in the supine position on an autocondensation cushion, which is connected to the generator. The patient is connected to the other terminal by means of the autocondensation handle, which he holds. In either technic, the operator places his hand on the surface to be treated, and then the main switch is turned on. *The hand of the operator must not be removed from the patient while the current is on. Otherwise, an arc would be established between the operator's hand and the patient.* The current is increased until tolerance is reached. The operator's hand is kept in motion, giving massage at the same time heat is being generated within the patient's tissues. *When necessary to terminate the treatment, the current must be*

turned off before the operator's hand is removed from the patient.

2. Indirect diathermy may be given also by means of non-vacuum or vacuum glass electrodes. The glass electrodes are made in various shapes for both surface and orificial applications. Figure 7a shows a vacuum electrode, coated internally with silver deposition, with insulated handle, and provided with a connection ring for making contact with the conducting cord from a diathermy machine. If not provided with an insulated handle as an integral part of the electrode, a separate insulating handle with a clamp to hold the electrode must be used by the operator when applying high frequency energy. A vacuum electrode of the condenser type is shown in Figure 7b provided with an insulated handle. Connection with the metal plate of the electrode is made by means of the connection ring as shown in the figure. The metal plate and the surface of the patient's skin constitute the plates of a condenser, the dielectric of which is the vacuum between the plate and the flat glass surface together with the glass itself. The electrode is connected to the high voltage terminal of the generator. According to the degree of heat required, it may or may not be necessary to ground the remaining terminal. When only one terminal is used, the application is called *monopolar*. Grounding the other terminal decreases the impedance to the flow of current, and consequently for the same voltage a greater current flow results.

If the patient is lying on an autocondensation cushion and is connected to the generator as previously outlined, the glass electrode can be applied to the patient without any connection to the machine. Actually the electrode is capacitively grounded through the operator. Care must be taken to have the current switched off, however, before applying or removing the electrode. Before treatment, the skin over which the electrode is to be moved should be dusted with talcum powder. Without talcum powder, the electrode cannot be moved readily at a uniform rate over the surface.

To produce counter-irritation, apply a thin layer of towelling over the area, and then make the electrode application. The thickness of the towel will determine the length of the spark discharge. These discharges produce counter-irritation. Care must be taken to keep the electrode in motion; otherwise, a burn may occur.

In our opinion, indirect diathermy is of little, if any, value. However, many clinicians still use it and claim excellent therapeutic results from its use. For a résumé of its field of application, the reader should consult Bierman's or Kovacs' excellent book.

#### AUTOCONDENSATION

According to Kovacs, autocondensation is a modified form of general diathermy. There are two types of autocondensation cushions in use. One consists of a metal plate, approximately 72 inches by 30 inches, over which is placed a 4-inch layer of silk floss, the entire cushion including the plate being covered with a tufted leather casing. When a patient is lying on the autocondensation cushion, the metal electrode forms one plate, the silk floss the dielectric, and the patient the other plate of a condenser. The other type of cushion consists of a metal plate covered with an insulating fiber material about  $\frac{1}{2}$  inch thick. This cushion is hinged so that treatment may be given in the sitting or supine positions. The type of cushion best suited for this form of therapy is problematical. Each type has its advocates.

The cushion is connected to the high voltage terminal of the generator. The patient lies on the cushion with his head well supported by a pillow. The arms are flexed at the elbows to a right angle. An autocondensation metal handle, connected to the remaining terminal, is held with the hands separated as far as possible. The metal handle rests on a pillow, placed on the chest of the patient to provide a support. After the current is switched on, no one should be permitted to touch any part of the patient or a spark sufficient to cause a burn may be established between the patient and the person making the contact.

The current intensity employed usually ranges from 500 to 1,200 ma. The treatment is given for 30 to 45 minutes. For evaluation of this treatment see Kovacs and Bierman.

### SHORT WAVE DIATHERMY

As already discussed under the fundamentals of high frequency currents, the development of the thermionic vacuum tube made possible the generation of currents of much higher frequency than those employed in conventional diathermy, and consequently made possible modification in methods of applying high frequency energy for medical purposes. The frequencies employed in short wave diathermy range from 10,000,000 to 100,000,000 cycles per second, the frequency employed in any given application being that best suited for the transfer of energy to the patient for the technic used. The range in wavelength, corresponding to the frequency range of 10,000,000 to 100,000,000 cycles per second, is 30 to 3 meters.

The methods in common use of introducing high frequency electric energy into tissue for the purpose of generating heat fall into two distinct classifications, namely: one, the use of a high frequency electric field (the so-called condenser field); and two, the use of a high frequency induction field. The electrodes employed in short wave diathermy are different from those used in conventional diathermy. As already explained, conventional diathermy is applied by means of bare metal electrodes in direct contact with the skin. With short wave diathermy, on the other hand, insulated metal electrodes are employed. It is true that bare metal electrodes can be used, but because of the definite danger of burning the patient with such electrodes, they should not be employed.

### HIGH FREQUENCY ELECTRIC FIELD

High frequency energy may be applied to tissues by placing the tissues to be heated between plates on which a high frequency potential is impressed. The high frequency electric field generates heat in the tissues. The heat developed results from

resistance and dielectric hysteresis losses within the tissues.

**Electrodes.** The electrodes used with the high frequency electric field, or the *condenser field* as it is more popularly known, consist of *pad electrodes*, *cuff electrodes*, and *air-spaced electrodes*.

A pad electrode consists of a flexible piece of metal vulcanized between two layers of rubber, making a total electrode thickness of approximately  $\frac{3}{8}$  inch. Such electrodes vary both in size and shape. They are known as *pad electrodes* by some, and as *condenser electrodes* by others (Figure 8). A long insu-

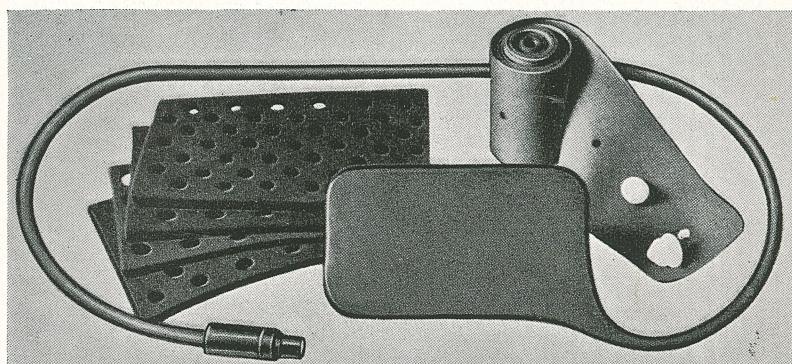


FIGURE 8. Pad electrode for short wave diathermy.

lated conducting lead is attached to the electrode for making connection to the short wave generator.

Cuff electrodes are nothing but pad electrodes of such length and width that they may be applied as cuffs, completely encircling a region of the body. They are employed chiefly for the treatment of joints (Figure 9). A pad electrode and a cuff electrode are occasionally used in combination (Figure 10).

One type of air-spaced electrode is made of a metal plate placed between two thick layers of rubber or other insulating material, and may or may not be flexible. The electrode is provided with an adjustable guard so that the air-space between tissue surface and electrode may be maintained at a given value. Such electrodes vary in shape and size. Another type of air-



FIGURE 9. Cuff electrodes.

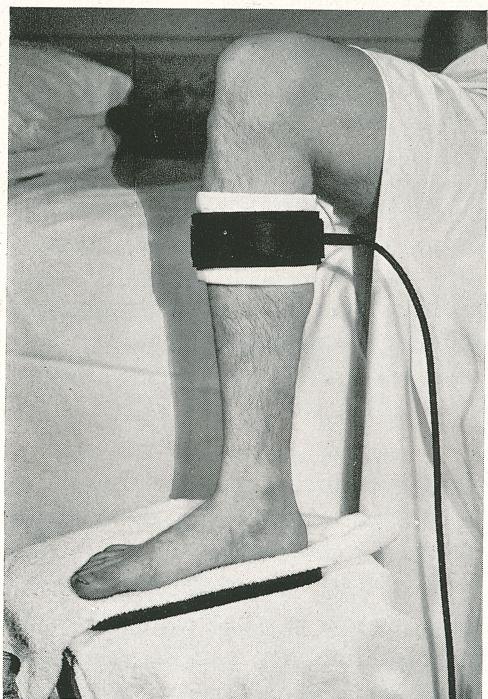


FIGURE 10. Application of cuff and pad for treatment of the ankle. (From KRUSEN: *Physical Medicine*. Courtesy W. B. Saunders Co.)

spaced electrode consists of an appropriately shaped glass or plastic vessel to serve as an insulator and spacer, and a rigid metal plate. The plate is movable within the cylindrical vessel; this enables the operator to adjust the distance between the metal plate and the skin. For different machines, different spac-

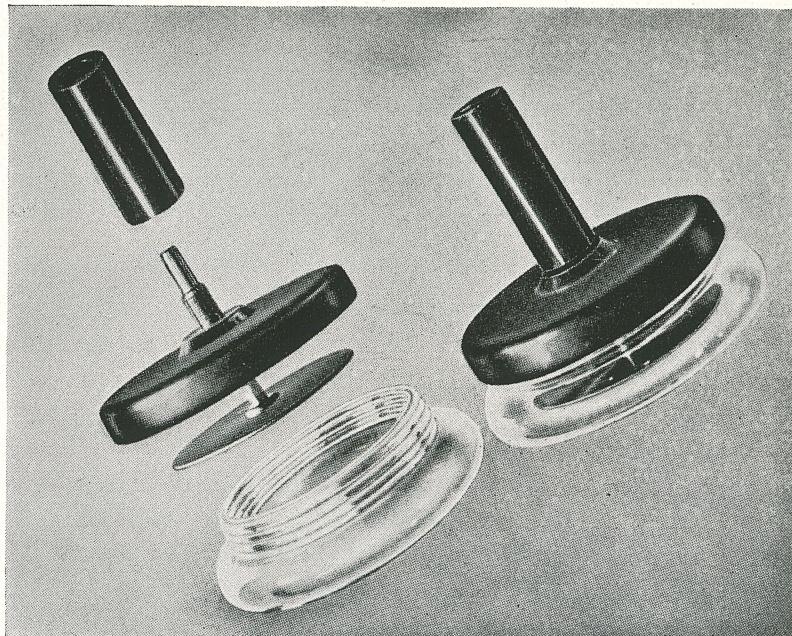


FIGURE 11. Air spaced electrode.

ings may be required (Figure 11). Electrodes of this type dispense with the necessity of using felt or towelling as spacers, since the proper spacing is provided by the air gap. Hence, these electrodes are called air-spaced electrodes.

Various adaptations of the type of electrodes discussed in the foregoing paragraphs have been devised for orificial application. Such electrodes are used with a pad, a cuff, or a large air-spaced electrode as the dispersive electrode. We are not convinced that such highly localized orificial treatment is either necessary or desirable. *In our opinion generalized pelvic heating is just*

as effective and probably preferable for the treatment of vaginal, rectal, and prostatic conditions.

Pads, cuffs, and the cuff and pad electrodes are applied in the same manner as the bare metal plates, cuffs, and plate and cuff electrodes for conventional diathermy, with the exception that an appropriate thickness of felt or bath towelling is placed between the skin surface and the rubber surface of the electrodes. The proper thickness of the felt, or other dielectric material that will assure satisfactory operation, will vary with different generators, and therefore should be specified by the manufacturer. Both pads and cuffs have conducting leads attached so that they may be connected to the generator.

#### SPECIFIC TECHNIC OF APPLICATION

1. **Double Pads. (Through and Through Application.)** The pads may be of the same or of dissimilar area. When they are of the same area, the current density in the tissues adjacent to the electrodes will be the same. If it is desired to generate heat at a greater rate in the tissues near one electrode, an electrode smaller in area is placed over that region. This electrode is designated the *active* electrode. The larger electrode is known as the *dispersive* electrode. The rules outlined for the application of conventional diathermy, which pertain to the relationship of the current path through the tissues between the electrodes to the current path over the surface from the edge of one electrode to the other, must be observed. Furthermore, it must be kept in mind that with the much higher frequencies used in short wave diathermy, current leakage occurs more readily. In fact, current paths which conduct but little current at the frequencies employed in conventional diathermy will conduct appreciable currents at the frequencies used in short wave diathermy.

Before application of the electrodes, a towel one layer thick is applied over the area to be treated. The proper thickness of spacing is then applied over the towel. Information of the dielectric material and the appropriate thickness to be used for best

operation of a generator should, as already stated, be provided by the manufacturer and the user of such apparatus should carefully follow these recommendations.

The electrodes are held in place either by an elastic bandage or by a sandbag. As with conventional diathermy, care must be taken to prevent the edges from digging into the tissues; and

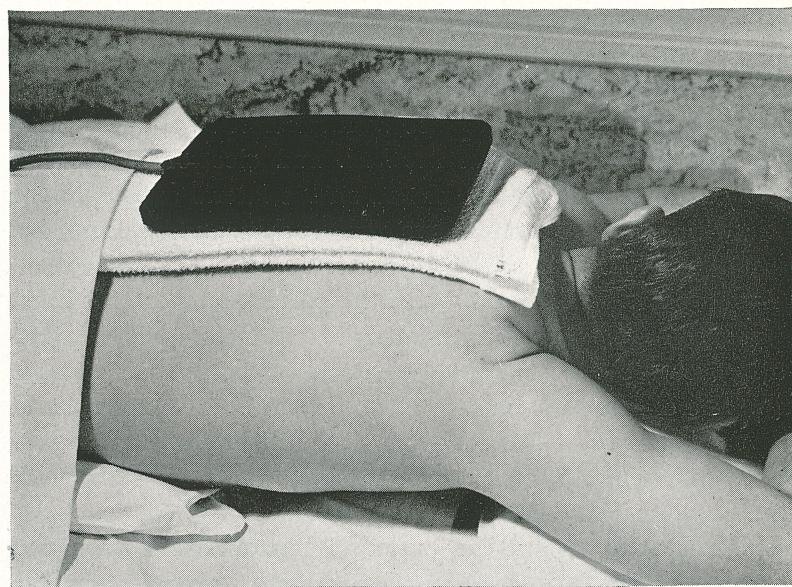


FIGURE 12. Application of pad electrodes to the dorsal spine. (From KRUSEN: *Physical Medicine*. Courtesy W. B. Saunders Co.)

also, contact between electrode assembly and skin must not be too tight (Figure 12).

**Frontal Sinus.** An active electrode, approximately 2 by 4½ inches, is placed over the region of the frontal sinus, with a towel of appropriate thickness between it and the skin, and held in place by a suitable bandage. A dispersive electrode, approximately 5½ by 8½ inches, is placed over the upper dorsal spine, with a towel of appropriate thickness between it and the skin, and held in place with an elastic bandage.

**Antrum, Temporomandibular Joint, Mandible, and Throat.** The method is similar to that described for the frontal sinus, with the active electrode placed over the part to be treated. The same principles of obtaining concentration of heat may be followed in applying the condenser electrodes with the short wave apparatus as are followed when applying the metal plate electrodes of conventional diathermy, except that with short wave diathermy it is not necessary to be so exacting.

**Ears.** Pad electrodes, approximately 4 by  $7\frac{1}{2}$  inches, are placed over each ear, with one or more towels between them and the skin, and held in place with an elastic bandage.

**Spine (Cervical). Lateral Method.** Pad electrodes, approximately 2 by  $4\frac{1}{2}$  inches, are placed on the lateral aspects of the neck, with a towel between them and the skin, and held in place with an elastic bandage.

**Anteroposterior Method.** With the patient lying on his back, a pad electrode, approximately 4 by  $7\frac{1}{2}$  inches, is placed posteriorly over the cervical spine, with a towel between it and the skin. The electrode is held in place by a rubber sponge placed between it and the pillow. A dispersive electrode, approximately  $5\frac{1}{2}$  by  $8\frac{1}{2}$  inches, is placed over the upper anterior chest, with a towel under it, and held in place by a sandbag.

**Spine (Dorsal).** With the patient lying on his back, a pad electrode, approximately  $5\frac{1}{2}$  by  $8\frac{1}{2}$  inches, is placed under the part of the dorsal spine to be treated, with a towel between it and the skin. The dispersive electrode, approximately 12 by 15 inches, is placed over the front of the trunk, with a towel between it and the skin, and held in place by sandbags.

**Lumbosacral and Sacro-Iliac Regions.** The application for these regions is the same as for the dorsal spine, except that the active electrode, approximately  $5\frac{1}{2}$  by  $8\frac{1}{2}$  inches in dimension, is placed under the region to be treated.

**Shoulder.** With the patient lying on his back, a compression bladder, slightly inflated, is placed under the shoulder to be treated to hold the electrode, about 4 by  $7\frac{1}{2}$  inches, in good contact. A second electrode of the same size is applied over the

anterior surface of the shoulder, with a towel intervening, and held in place by means of a sandbag.

**Subdeltoid.** With the patient sitting, an active electrode, approximately 4 by  $7\frac{1}{2}$  inches, is placed over the deltoid muscle, with a towel between it and the skin, and the electrode held in position by an elastic bandage. A dispersive electrode, approximately 12 by 15 inches, is placed under the opposite arm, over the lateral surface of the chest, and held in place by a bandage.

**Elbow.** Two electrodes of the same size, approximately 4 by  $7\frac{1}{2}$  inches, are used. The forearm is extended and supinated. One electrode is placed over the biceps and the other under the extensor surface of the forearm. Towels of appropriate thickness should be interposed between the electrodes and the skin. The electrodes are held in place by a bandage.

**Wrist and Hand.** An active electrode, approximately 2 by  $4\frac{1}{2}$  inches or 4 by  $7\frac{1}{2}$  inches, is placed over the wrist, a towel between it and the skin, and held in place by a bandage. A dispersive electrode, approximately 12 by 15 inches, is placed on the back, with towels interposed between it and the skin, and held in place by a bandage.

**Chest or Abdomen.** The area to be treated is sandwiched between two electrodes, with towels interposed between them and the skin. With the patient lying on a treatment table, the under electrode is held in place by the patient's weight and the upper one by sandbags. The electrodes usually used are two of equal size, either approximately  $5\frac{1}{2}$  by  $8\frac{1}{2}$  inches, or 12 by 15 inches, or an active electrode  $5\frac{1}{2}$  by  $8\frac{1}{2}$  inches, and a dispersive one 12 by 15 inches.

**Hip.** Pad electrodes, approximately  $5\frac{1}{2}$  by 8 inches, are placed anterior and posterior to the hip joint, with the patient lying on his back. Towels are interposed between the electrodes and the skin. The anterior electrode is held in place by a sandbag.

**Knee.** Two electrodes, approximately 4 by  $7\frac{1}{2}$  inches, are placed on the lateral and mesial surfaces of the knee joint, with the patient lying on his back on a treatment table. The knee

should be slightly flexed and supported by a pillow. Towels are interposed between the electrodes and the skin. The electrodes are held in place over the calf by means of a woven elastic bandage.

**Ankle and Foot.** With the patient sitting on a chair, his foot is placed on an electrode, approximately 4 by  $7\frac{1}{2}$  inches, with a towel between it and the sole of his foot. Another electrode of the same size, with a towel between it and the skin, is held in place over the calf by means of a woven elastic bandage.



FIGURE 13. Air spaced electrodes within glass containers.

**2. Plate and Cuff (Longitudinal Method).** This technic is used for the treatment of a wrist, ankle, or specific regions of the foot and hand. The most fleshy part of the forearm or lower leg is encircled by a cuff, with proper spacing between the electrode and the skin. When it is desired to heat the wrist, the hand is placed, palm down, on a pad electrode with the necessary spacing between the electrode and the skin surface. Similarly, the foot is placed on a pad electrode when treatment is to be given to the ankle joint. The cuff electrode is bound and retained in position by an elastic bandage, and a sandbag is placed on the

hand or foot of the patient to maintain proper contact of hand or foot with the pad electrode. If only a region of the hand or foot is to be treated, that particular region of the hand and foot alone should make contact with the pad electrode. A cuff and pad application is illustrated in Figure 10.

**3. Double Cuffs.** This technic is used for the treatment of the elbow and the knee. The technic of application is illustrated

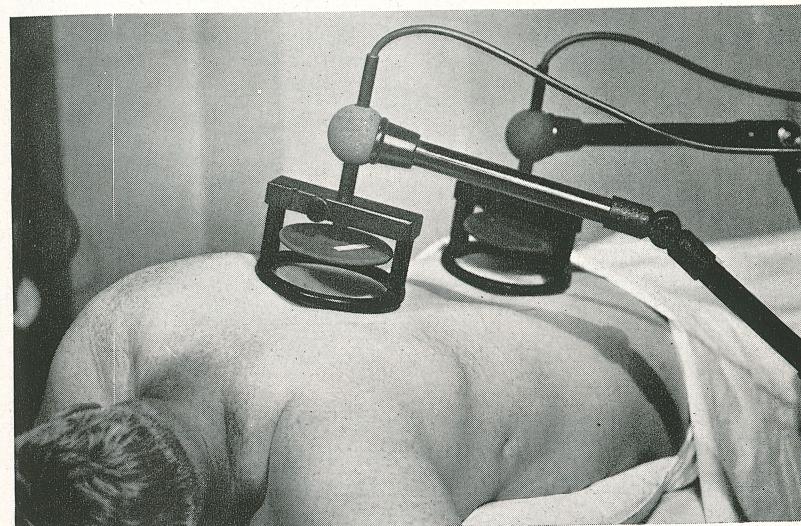


FIGURE 14. Air spaced electrodes. Plate covered with insulation and provided with an adjustable spacer.

in Figure 9. It is important, as pointed out in the section on conventional diathermy, that the arms and legs be kept fully extended to avoid excessive heating along the inner surface of the joint.

**4. Air-spaced Electrodes.** These electrodes are applied in exactly the same manner for the treatment of various parts of the body as are the pad electrodes. The application differs, however, in that air is used instead of felt or towelling for spacing between the electrodes and the skin. Figures 13, 14 and 15 illustrate the application of these electrodes.



FIGURE 15. Flexible air spaced electrodes without spacers.

**Evaluation of the High Frequency Electric Field Method of Application.** Because the patient usually experiences a marked sensation of heat on the skin surface, it has been erroneously assumed by many that the applications described above are more effective for heating the deeper tissues of the body than those applications and technics which do not heat the skin surface excessively. Experiments conducted on the thighs of living human subjects at Northwestern University Medical School have shown that, when the temperature of the skin is high, the temperature of the deeper tissues is proportionally low. Conversely, it was found that the rise of temperature in the deeper tissues was progressively higher as the surface temperature decreased. It was found that the induction field method of application, for example, produced less surface heating and consequently made possible the input of more energy into the tissues with resultant higher deep tissue temperature.

With the electric field method of application, whether by

pads, cuffs, or air-spaced electrodes, the impedance may not be uniform over the entire surface covered by the electrode. The non-uniformity of impedance will result in a non-uniform distribution of current over this surface. Excessive heating will occur where the current density is excessive. These areas of

TABLE I  
CAUSES AND ELIMINATION OF HOT SPOTS

Type of Electrode	Cause	Corrective Measure
Pad or Cuff	a. Concentration of perspiration in absorbent material	Replace with dry spacing material; in some cases sufficient to place dry towelling between skin and spacing material
	b. Non-uniform pressure of electrode on skin	Equalize pressure
	c. Non-symmetrical positioning of electrodes resulting in the edges on one side being closer together than the edges on the other	Reposition electrodes
Air Spaced	a. Pooling of perspiration on surface of skin	Dry surface
	b. Non-symmetrical position of electrodes	Reposition electrodes
	c. Non-uniform spacing between electrode and skin surface	Adapt electrode to conform to contour of skin surface; or increase air spacing so that irregularities in skin surface become negligible in comparison with average air spacing

excessive superficial heating are designated as *hot spots*. Such hot spots are a frequent cause of discomfort and skin burns, and care must be taken that they be eliminated. The causes of hot spots and the steps to be taken to eliminate them are set forth in Table I.

No high frequency generator is approved by the Council on Physical Medicine and Rehabilitation of the American Medical Association unless certain minimum requirements are met.

With respect to the heating efficacy of a short wave diathermy machine, the Council requires that such machines be capable of producing a final temperature of 103° to 104°F. in the deep muscles of the thigh at the end of a twenty minute application. At present no generator has been able to meet these requirements when the usual condenser pad applications are made.



FIGURE 16. Infrared photograph of burn after application of short wave diathermy by double cuff method.

The cuff technic does meet the Council requirements, but the high surface heating and development of *hot spots* make it a not too comfortable application. Furthermore, its application is limited to the extremities. Figure 16 shows an extensive burn of the thigh as the result of a double cuff application. The burns were directly beneath the electrodes. The patient was hospitalized within eight hours of the injury and continued under treatment in the hospital for one week. Only prompt attention prevented a very serious injury.

The air-spaced technic is the most comfortable of the high frequency electric field applications. To be effective, however, both electrodes must be applied to the same surface and in the same plane (Figures 13, 14 and 15).<sup>1</sup> Only this technic of apply-

<sup>1</sup> COULTER, J. S. and OSBORNE, S. L.: Short wave diathermy in heating human tissues, *Arch. Phys. Therapy*, 17:679, 1936.

ing air-spaced electrodes has succeeded in meeting the requirements of the Council on Physical Medicine and Rehabilitation for acceptable apparatus. Other technics, such as the *through and through method*, have been shown to be unsatisfactory. This then places marked limitations on its field of usefulness.

Table II summarizes the various technics of applying the high frequency electric field and their limitations.

TABLE II

Technic	Limitation
Pad	Does not meet requirements of Council on Physical Medicine and Rehabilitation, American Medical Association
Cuff	Meets requirements, but applicable only to the extremities
Air-spaced	Meets requirements, but only when electrodes are placed on same surface and in same plane.

**Operation of the High Frequency Generator for Electric Field Application.** Generators made by various manufacturers differ in construction and operation. Not only do their electrical circuits differ, but the various meters and controls provided for operation of the generator differ. It would be too great a task to describe each generator individually; hence we shall merely describe in a general way typical controls. Each manufacturer gives detailed directions for the correct operating of his particular generator, and these directions should be read and followed carefully.

All generators have one or more regulators to increase the intensity of the current taken by the patient. Another control is provided to tune the patient load into resonance with the generator. As this tuning control is moved from its zero position, the pointer of the resonance indicator moves from its zero position. When the condition of resonance has been reached, the pointer of the resonance indicator will have reached its maximum deflection. If the control is moved beyond this point, deflection of the pointer will decrease, the control being usually so designed that the decrease in deflection is relatively great for a slight increase

in rotation of the control beyond the point of resonance. The dial of this indicator frequently has a milliampere scale, and many therapists erroneously believe that the meter indicates the milliamperes delivered to the patient. This reading, however, usually bears no relationship to the energy absorbed by the patient, but merely serves to indicate when resonance has been established.

Some generators are provided with a milliammeter to indicate the plate current of the tube. In addition, some generators also provide a voltmeter to indicate the filament voltage of the tube. When these are provided, the filament voltage switch should be turned on first; then, when the correct voltage has been applied to the filament, the plate current switch is closed. The load circuit (i.e., the patient circuit) is then tuned to resonance. Some generators are provided with a voltage indicator, on the scale of which the zone of safe operation is marked.

The power output into the tissues under treatment may, if required, be increased by increasing the setting of the intensity control. After the intensity setting has been changed, the patient circuit should be retuned for resonance.

**Dosage.** As in the case of conventional diathermy, the dosage administered is determined by the energy input per unit time, i.e., the power, and the time of application. The intensity, or power input per unit time, is determined by the tolerance of the tissues of the patient. This tolerance will vary with the condition of the tissues, and no hard and fast rule as to wattage input per unit volume of tissue can be given. This is a matter that the judgment of the physician, based on knowledge of the condition of the tissues to be treated, must decide. The safer procedure is to employ a lower intensity and a longer period of application. As has already been pointed out, this technic of treatment presents definite advantages.

#### HIGH FREQUENCY INDUCTION FIELD (INDUCTOTHERMY)

High frequency energy may be applied to tissue through the agency of a high frequency magnetic field. This field is produced

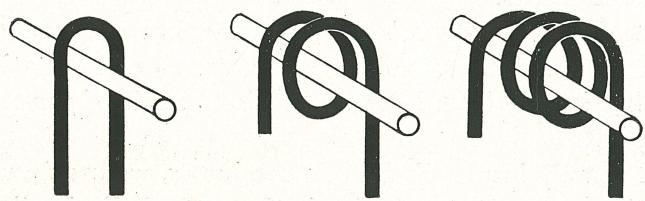
by means of a heavily insulated conductor, wound into a coil of appropriate configuration and number of turns, through which a high frequency current is conducted from an oscillator. The field set up about the coil induces eddy currents in the tissues in the field, such currents being most intense in the more conductive tissues.

**Electrodes.** The coil referred to in the foregoing constitutes the electrodes. The types of electrodes used for *Inductotherapy*, as the heating of tissue by the induction field has been termed, are:

1. A heavily insulated, flexible conductor, wound around or about the part to be treated in the form of a helical coil.
2. The same type of cable wound into a flat or pancake type of coil, which is placed over the part to be treated; or wound into two coils in such a manner that their fields are additive and placed in opposition on either side of the tissues to be treated.
3. A flexible or solid conductor wound into a permanent coil of suitable size, number of turns, and configuration and enclosed within a casing or drum of a non-conducting material to form the so-called *disk* or *drum electrode*.
4. A flexible or solid conductor wound into two coils of suitable configuration and number of turns, placed within casings or drums, and so connected in series or parallel that the fields of the two coils will be additive to form the so-called *adjustable disk* or *drum electrode*. This electrode is so placed that tissues to be treated are subjected to the field obtaining between the coils. This electrode facilitates the application of the induction field and provides a means of readily adapting the application to the anatomy of the part to be treated.

As already stated, the cable electrode may be applied either in the form of a helical coil wound around the part to be treated or in the form of a flat "pancake" type of coil so placed that the part to be treated will be subjected to the high frequency induction field of the pancake coil. The number of turns is usually from one to three for both forms of application. In Figures 17a and 17b are shown the two types of applications using differ-

ent numbers of turns. Too many turns must not be employed, otherwise the coil will cease to act as an inductance and will act as a distributed cuff, permitting current to flow from turn to turn through the superficial tissues with resultant high skin heating.



TURNS, LOOP TECHNIC



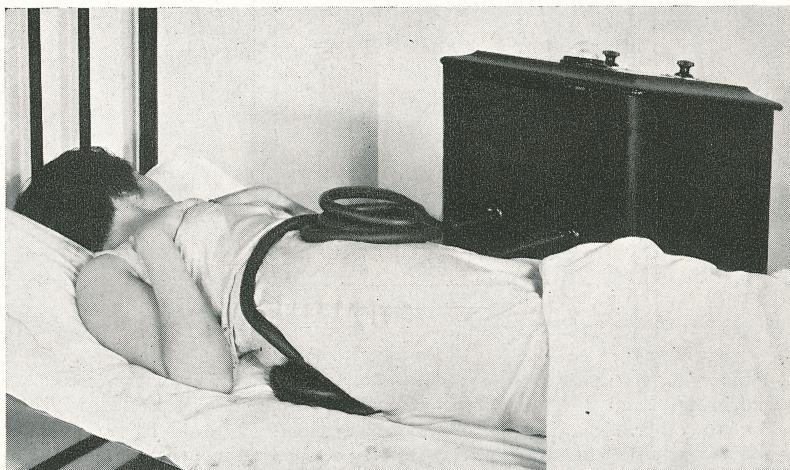
TURNS, PANCAKE COIL TECHNIC

FIGURE 17a and 17b. (a) Turns, loop technic. (b) Turns, pancake coil technic.

Furthermore, adequate spacing between turns must be provided, otherwise leakage of current from turn to turn through the superficial tissues will take place because of the reduced capacitive reaction between the turns. The spacing between the turns should be not less than 2.5 to 3 inches. Most manufacturers provide spacers of insulating material to assure proper spacing of the cable. These spacers are designed to provide the proper spacing for a particular machine and cable. The spacers used should be those provided by the manufacturer of the generator being employed. It is also important that the cable be separated by a suitable spacer at points of crossing, otherwise

excessive leakage of current will take place at these points with reduction of input into patient and excessive heating of the cable insulation at the points of crossing. In the figures illustrating the technics of application the proper use of spacers is shown.

Sufficient towelling or other absorbent padding should always be between the cable and the part being treated. To obtain

FIGURE 18. Double pancake coil application. (From MERRIMAN, HOLMQUEST, and OSBORNE: *Physiotherapy Rev.*, 14:107, 1934.)

maximum efficiency it is important that the details of the following technics be carefully observed. Towelling and other absorbent material used for spacing compresses under pressure. The thickness of the padding recommended in the following technics is the thickness of the padding after the coil is positioned and treatment is to be started.

As already mentioned, disk or drum applicators are also used. These disk or drum applicators contain permanently wound coils of the requisite number of turns and with proper spacing between turns to assure efficient operation of the generator. When using such applicators, spacing between skin and surface

of applicator is also provided by a suitable thickness of towelling or other absorbent material.

A double pancake coil, of two to three turns in each coil, so wound that their fields are additive, is also used. The part to be treated is placed between the two coils as shown in Figure 18. The coils are wound in the manner illustrated in Figure 19. As the current flows through the two coils, which are wound in

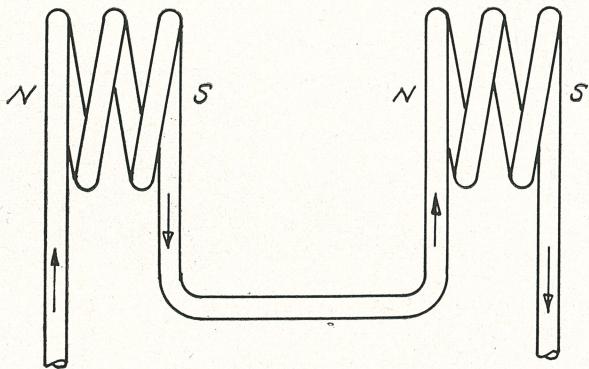


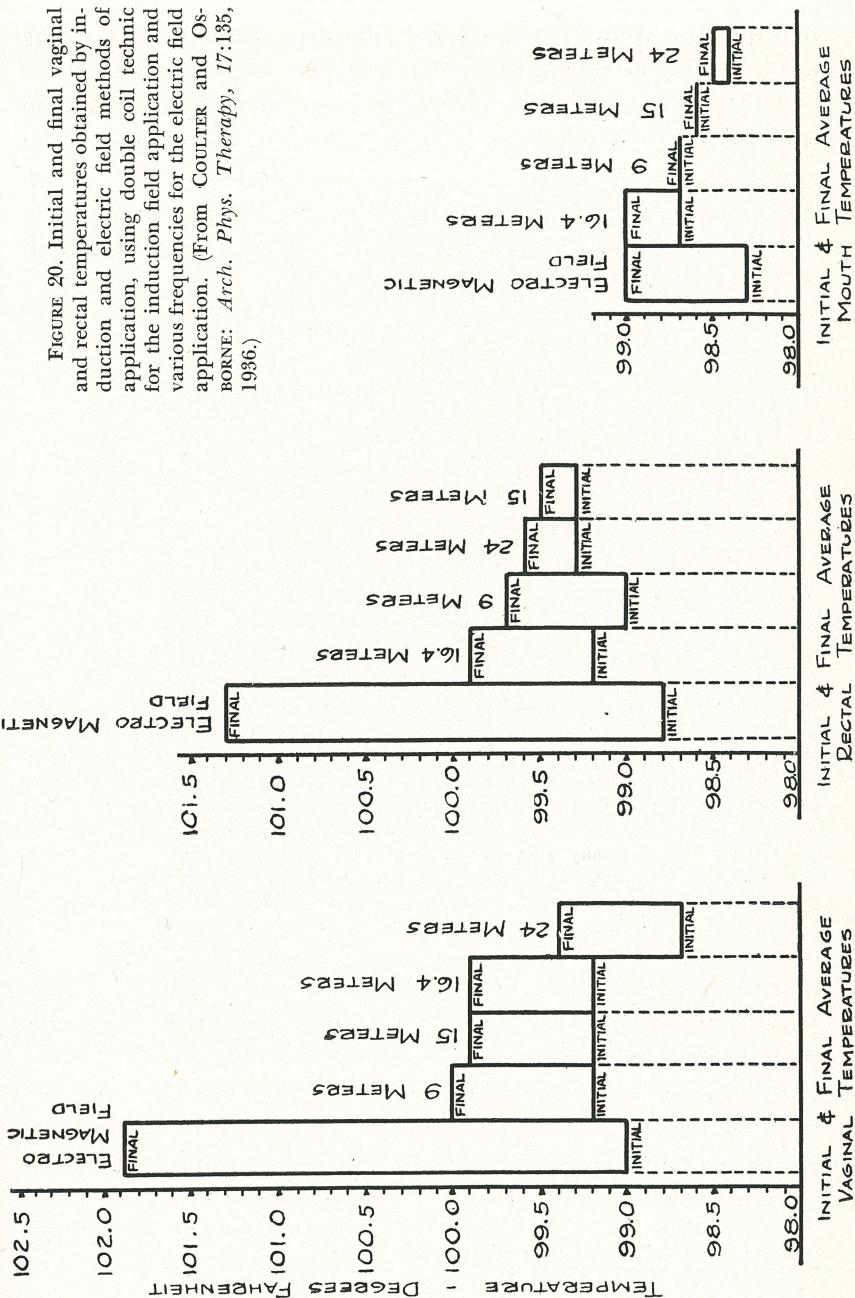
FIGURE 19. Schematic representation of the additive effect of two coils connected in series and so wound that the magnetic field of one is in phase with the field of the other. Assuming the instantaneous current flow to be in the direction of the arrows with closed heads, the polarity of the coils will be as indicated in the figure; and the lines of magnetic flux, which are continuous and close upon themselves, will thread the two coils, emerging at the north pole of the first coil, spreading out into space, and returning at the south pole of the second coil. Obviously the coils may also be connected in parallel to obtain an additive magnetic effect. Furthermore the coils may be of the flat, "pancake" type. Practical application of this principle to short wave diathermy was first reported by Merriman, Holmquest, and Osborne. (*Physiotherapy Rev.*, 14:107, 1934.)

series, the field of the first coil is in phase with that of the second. Should the two coils be wound in opposite directions, their fields would be out of phase and thus oppose each other. Care must be taken when using this technic that the coils are both wound in the same direction. Coils connected in parallel and so wound that their fields are additive could also be used.

Measurements were made by Coulter and Osborne<sup>2</sup> of the

<sup>2</sup> COULTER, J. S. and OSBORNE, S. L.: Short wave diathermy: A comparative study in pelvic heating. *Arch. Phys. Therapy*, 17:135, 1936.

FIGURE 20. Initial and final vaginal and rectal temperatures obtained by induction and electric field methods of application, using double coil technic for the induction field application and various frequencies for the electric field application. (From COULTER and OSBORNE: *Arch. Phys. Therapy*, 17:135, 1936.)



heating produced in the female pelvis by various methods of applying high frequency fields. These measurements demonstrate the effectiveness of the double coil technic. In Figure 20 the initial and final temperatures attained in the vagina and

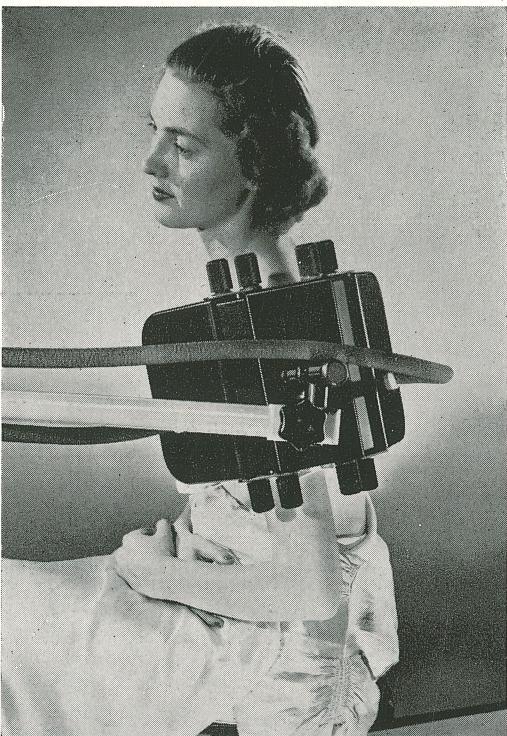


FIGURE 21a. Adjustable drum applied to shoulder.  
(Courtesy General Electric X-Ray Corp.)

rectum by the induction field and by the electric field of various frequencies are shown. The double coil technic of applying the induction field was far superior to the electric field pad applications.

Adjustable disk or drum electrodes, utilizing the double coil principal of application, are available. The advantage of this type of electrode is its convenience in application to anatomical configuration, facilitating treatment of such parts, for example,

as the shoulder, hip, and face. It can also be used to advantage in the treatment of other parts of the body. Towelling or other absorbent material should be used with this applicator as with other methods of applying the induction field, Figures 21a and 21b.

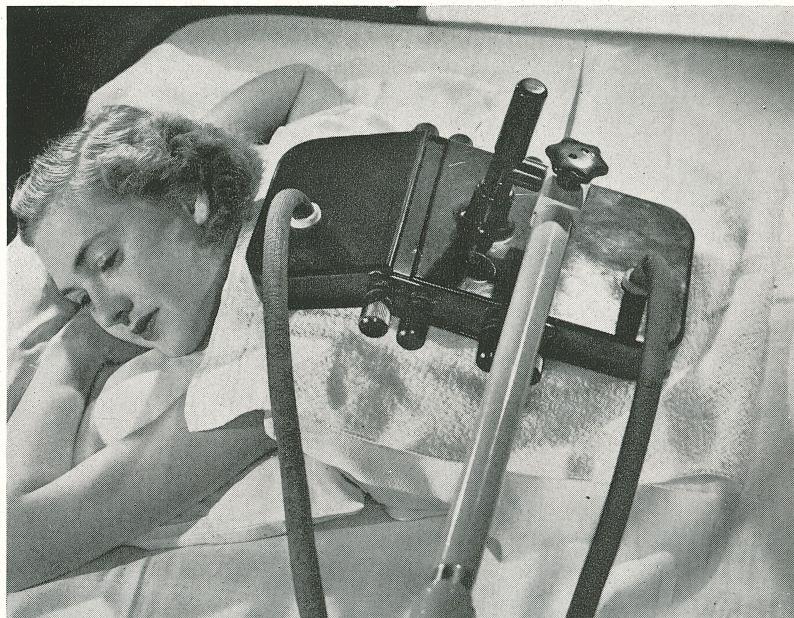


FIGURE 21b. Adjustable drum applied to dorsal spine.  
(Courtesy General Electric X-Ray Corp.)

**Specific Techniques of Application.** Since the clinical results are attributed to the effects of hyperemia, care must be given to the establishment and maintenance of one which is adequate. Insulation of the part to be treated reduces heat loss and permits a high degree of efficiency. Material used for insulation, which is applied next to the skin, should be an absorbent material such as terry cloth or bath towelling to absorb the perspiration, and at the same time supply the proper spacing for maximum efficiency. Additional insulation against heat loss can be provided by covering the patient with a light blanket or sheet.



FIGURE 22. Elbow.



FIGURE 23. Forearm.



FIGURE 24. Ankle.

**Elbow, Forearm, Ankle, Knee, and Foot.** The method of applying the cable to these parts is shown in Figures 22, 23, 24, 25 and 26. The procedure to be followed in applying the cable and administering the treatment is as follows:

1. Wrap sufficient towelling around the part so that spacing, when electrode is positioned, is at least  $\frac{1}{2}$  inch.
2. Place three turns of the cable around the part, with the turns separated  $2\frac{1}{2}$  to 3 inches. Fasten the turns in position with the cable spacers as illustrated.
3. Connect the cable terminals to the generator, keeping the leads from the coil to the generator separated by a spacer.

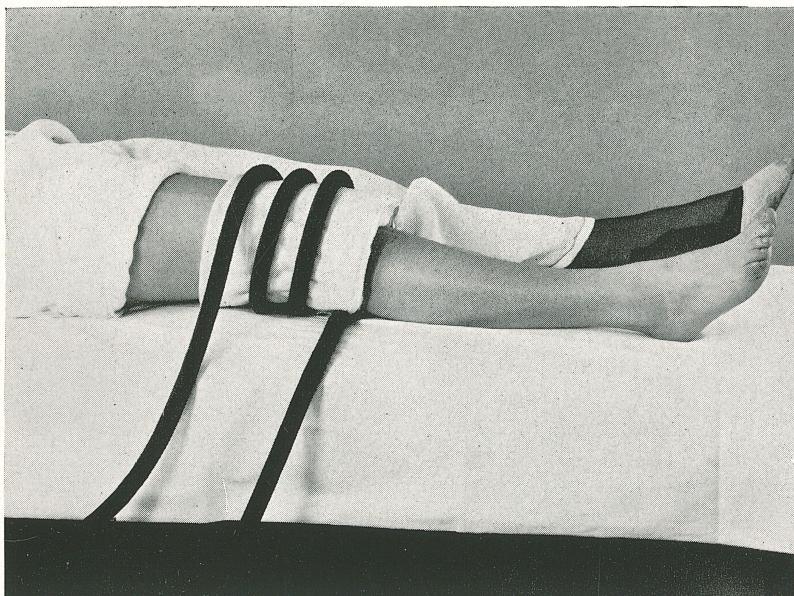


FIGURE 25. Knee.

4. Set intensity regulator for approximately  $1/2$  output.\*
5. Turn on current.
6. Adjust intensity setting as patient's tolerance indicates.

It is at times desired to treat both knees, both ankles, or both feet simultaneously. Figure 27 illustrates the method of applying the cable. When using this technic it is necessary to place a folded bath towel, at least 1 inch in thickness, between the two parts being treated. The towelling for spacing is then wrapped around both parts, and application of cable is made as for the treatment of a single part.

*Hand and Wrist.* 1. Form cable into a pancake coil of three turns, fixing coil position by spacing as illustrated (Figure 28).

2. Place  $1/2$  inch of bath towelling on cable as illustrated. Have

\* In the technics to follow, points 4, 5, and 6 will not be repeated to avoid useless repetition. It is understood however that these instructions are to be observed.

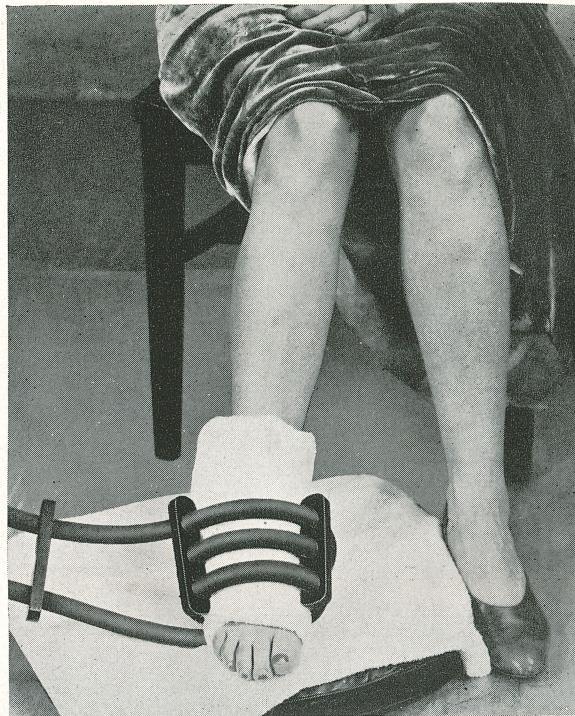


FIGURE 26. Foot.

patient grasp towelling around far side of cable with hand to be treated, and rest forearm across towelling on near side of cable.

*Upper and Lower Extremity (Entire).* 1. Wrap  $1/2$  inch of bath towelling around extremity as shown in Figure 29.

2. Place a single loop the full length of the extremity, and secure in position with an elastic band or a bandage.

3. Connect cable to generator, keeping leads separated by a spacer.

*Upper or Lower Extremity (Entire or Part).* 1. Wrap  $1/2$  inch of bath towelling around extremity.

2. Place two turns of the cable over the extremity or part to be treated, and secure in position with spacers as illustrated Figure 30.

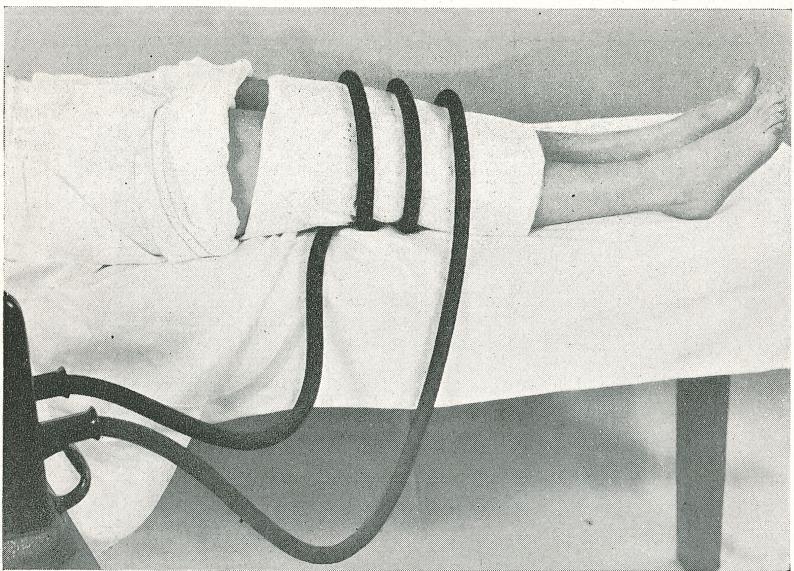


FIGURE 27. Both knees.

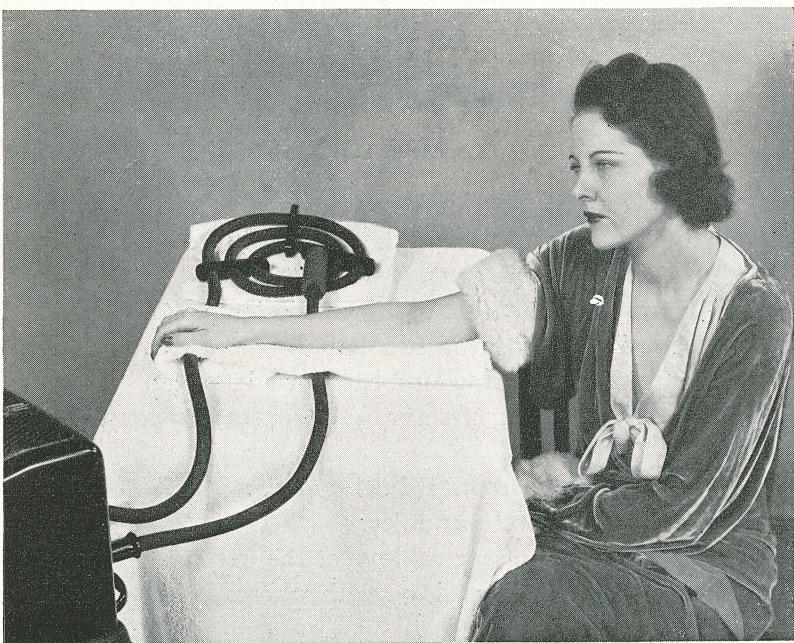


FIGURE 28. Hand and wrist.

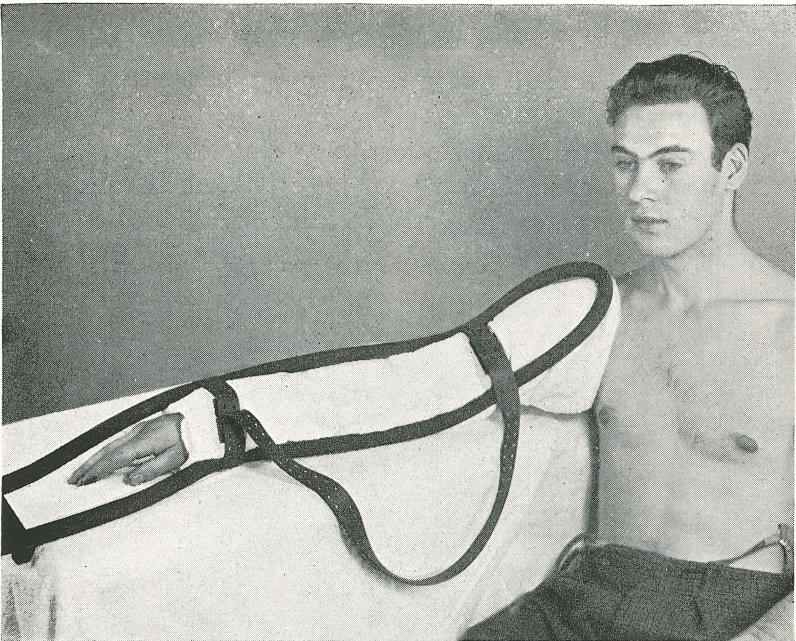


FIGURE 29. Upper or lower extremity (one turn).



FIGURE 30. Upper or lower extremity (two turns).

3. Connect cable to generator, keeping leads from coil to machine separated by a spacer.

*Shoulder.* 1. Place  $\frac{1}{2}$  inch of bath towelling over the shoulder. 2. Form the cable into a pancake coil of three turns and attach spacers. Place coil on towelling in apposition with shoulder, keeping it in place with an elastic strap or sandbag (Figure 31).

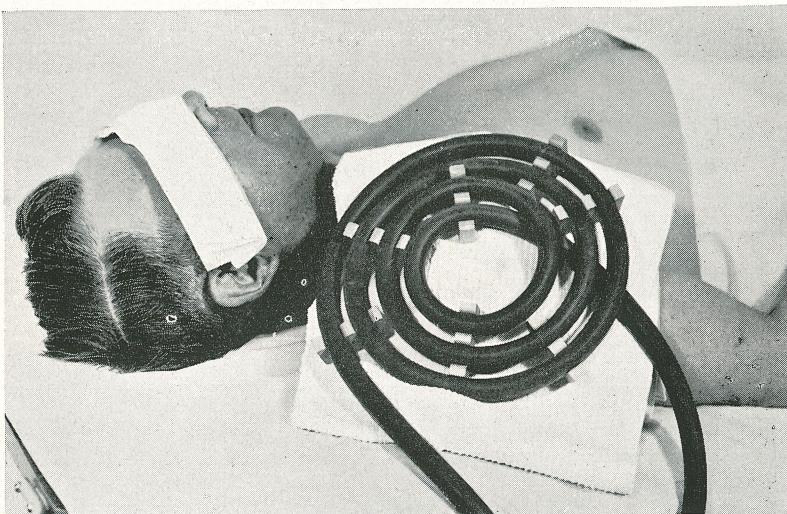


FIGURE 31. Shoulder.

3. Connect cable terminals to generator, keeping leads separated by a spacer.

*Ear or Sinus.* 1. Form the cable into a pancake coil of three turns, and attach spacers as illustrated in Figure 32.

2. Place a pillow over the coil.

3. Position the patient with the region to be treated in apposition with the coil (Figures 33 and 34).

4. Connect cable terminals to the generator, keeping the leads separated by a spacer.

*Neck.* 1. Place  $\frac{1}{2}$  inch of bath towelling over the neck.

2. Form the cable into a coil of two turns, and attach the

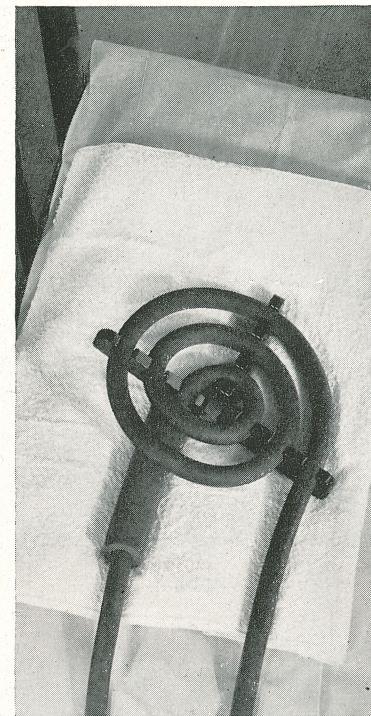


FIGURE 32. Coil in position for ear or sinus application.

spacers. Place the coil on the towelling. Support the lead across the chest with a pillow (Figure 35).

3. Connect cable terminals to the generator, keeping the two leads separated by a spacer.

*Eye.* 1. Place  $\frac{1}{2}$  inch of bath towelling over the eye.

2. Form the cable into a coil of two turns, and attach spacers (Figure 36). Place the coil on the towelling.

3. Connect cable terminals to the generator, keeping the two leads separated by a spacer.

*Chest, Pelvis, and Dorsal and Lumbo-sacral Spine.* 1. Place  $\frac{1}{2}$  inch of bath towelling on the surface of the area to be treated.

2. Form the cable into a pancake coil of 3 turns and attach spacers. Place the coil on the towelling over the area to be



FIGURE 33. Ear.



FIGURE 34. Sinus.



FIGURE 35. Neck.

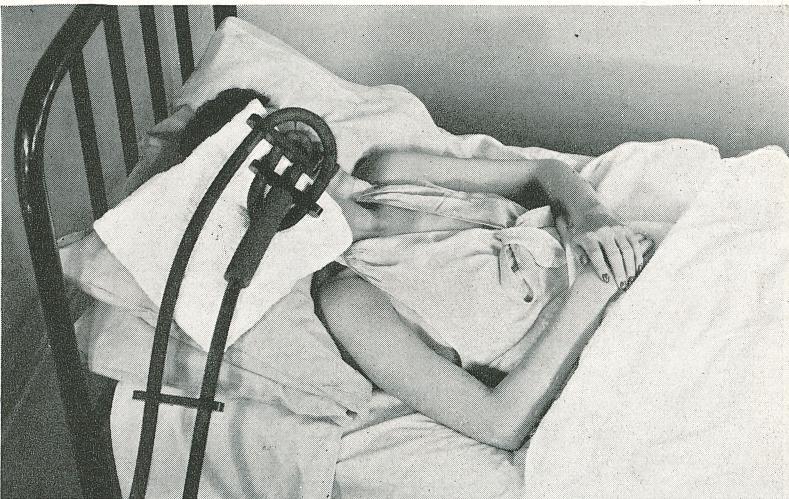


FIGURE 36. Eye.

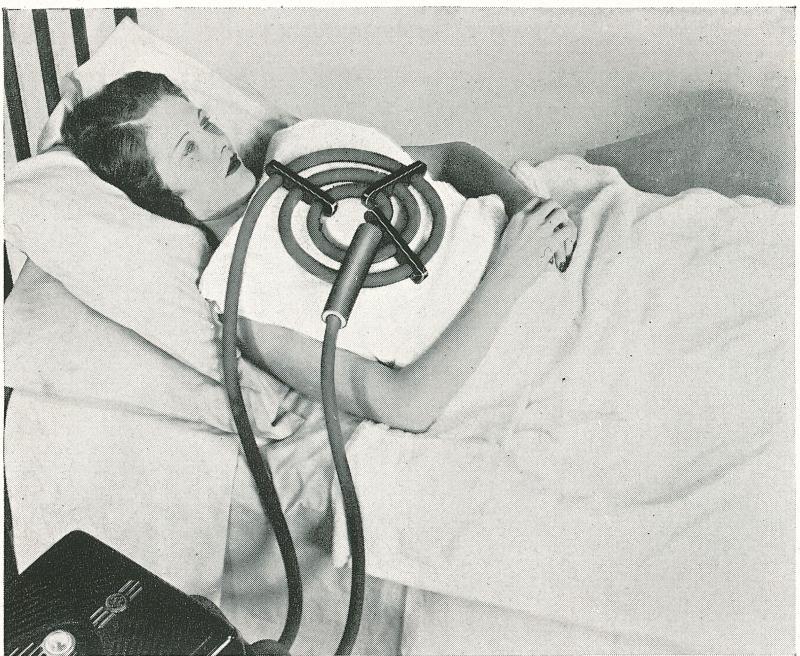


FIGURE 37. Chest.

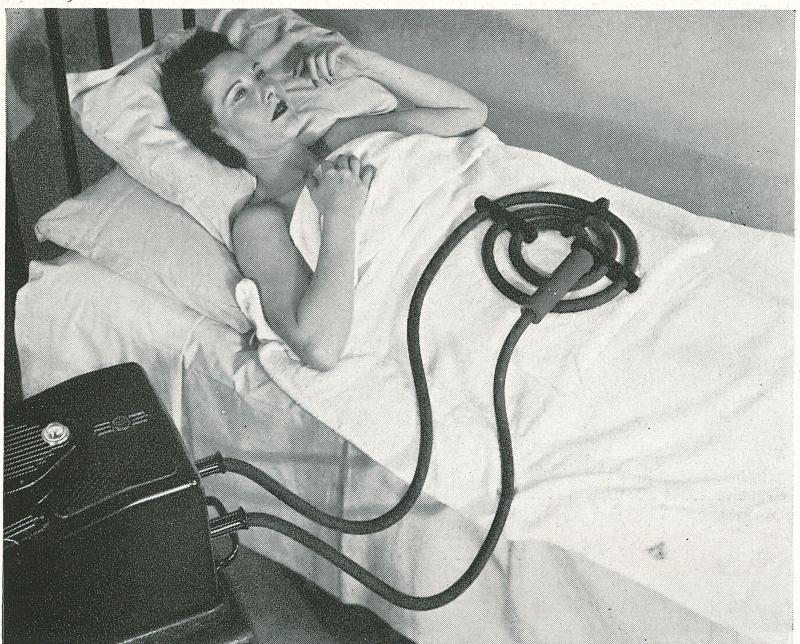


FIGURE 38. Pelvis.

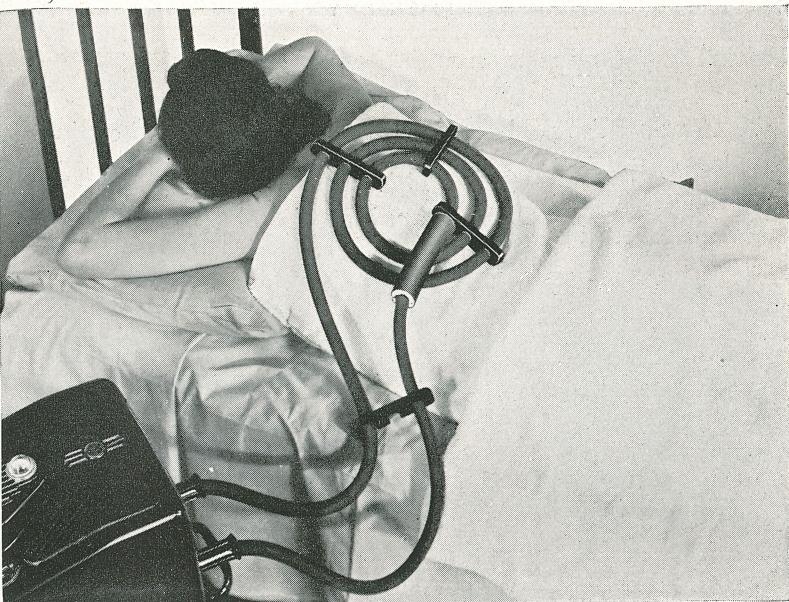


FIGURE 39. Dorsal spine.



FIGURE 40. Lumbo-sacral spine.

treated and in apposition with the part (Figures 37, 38, 39, and 40).

3. Connect the cable terminals to the generator, keeping the two leads separated by a spacer.

*Spine (Dorsal to Sacral Region).* 1. Place  $\frac{1}{2}$  inch of bath towelling over the back.

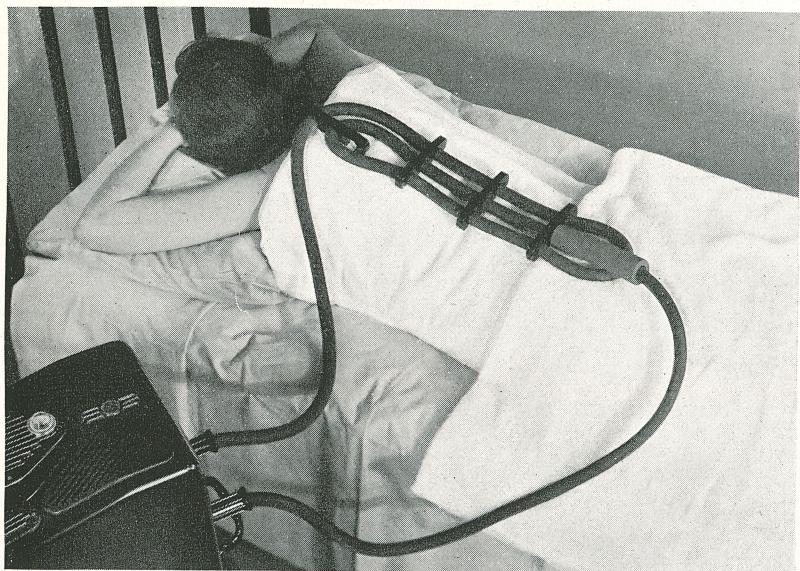


FIGURE 41. Entire spine.

2. Form the cable into an elongated coil and attach spacers. Place coil along spine (Figure 41).

3. Connect the cable terminals to the generator, keeping leads separated by a spacer.

*Prostate.* 1. Cover the seat of a *wood* chair with a layer of cardboard.

2. Place  $\frac{1}{2}$  inch of towelling or padding over the cardboard.

3. Form the cable into a pancake coil of three turns, attach spacers, and place on padding as illustrated (Figure 42).

4. Place a pillow of such thickness over the coil that, when the patient is seated, the spacing will be 1 to  $1\frac{1}{2}$  inches.



FIGURE 42. Coil in position for prostatic application.

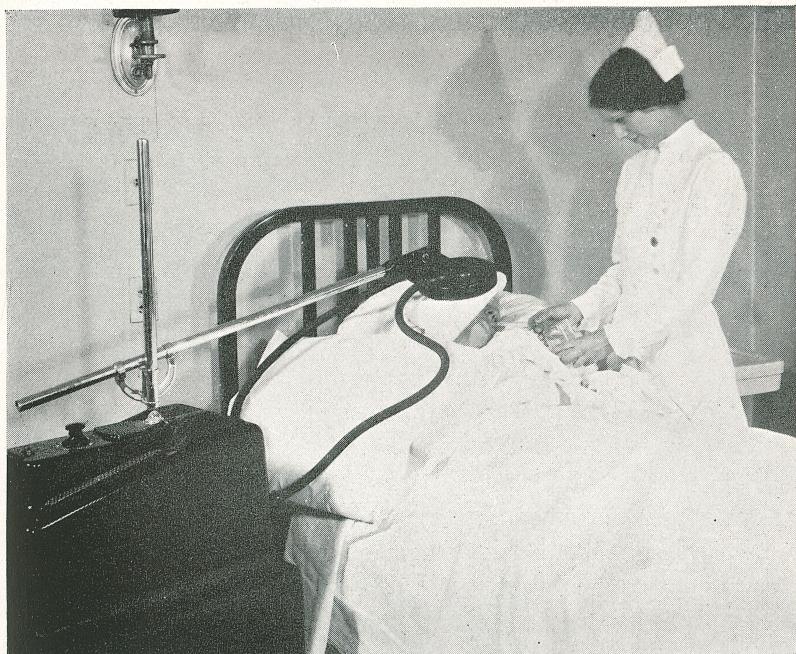


FIGURE 43. Sinus.



FIGURE 45. Ear.



FIGURE 44. Eye.

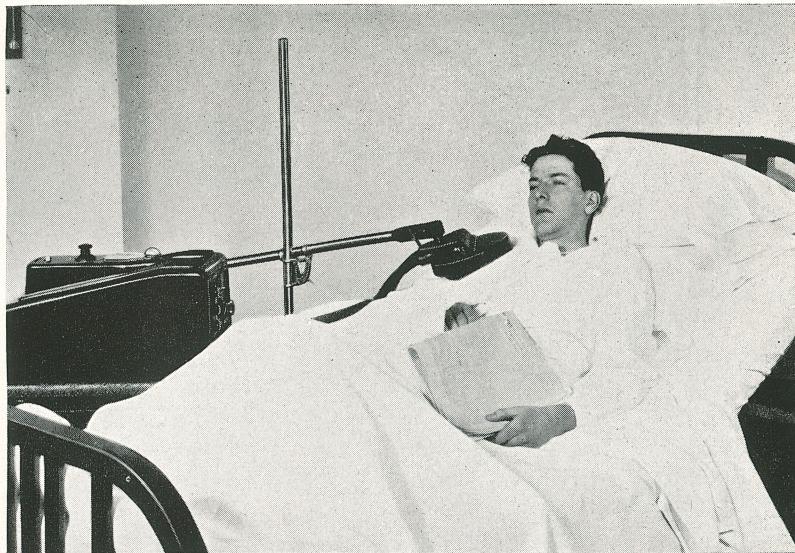


FIGURE 46. Shoulder.

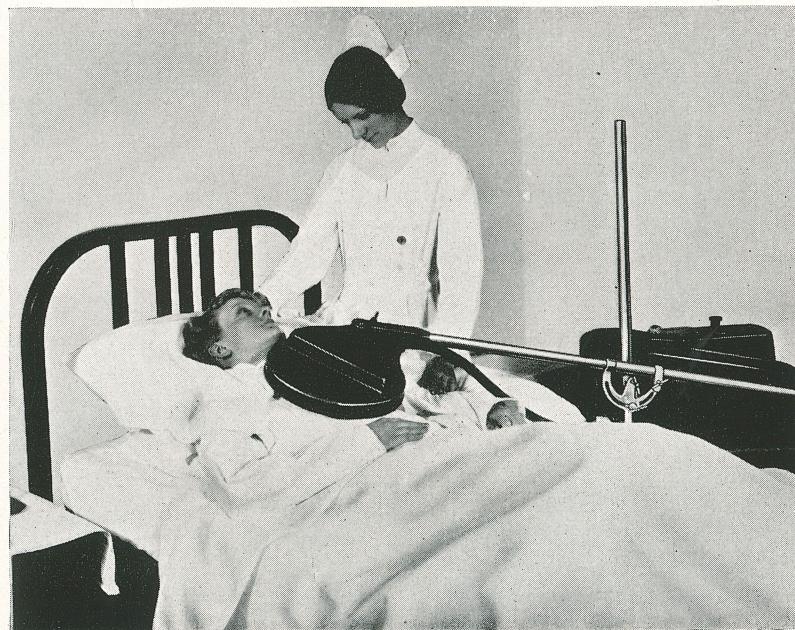


FIGURE 47. Chest.

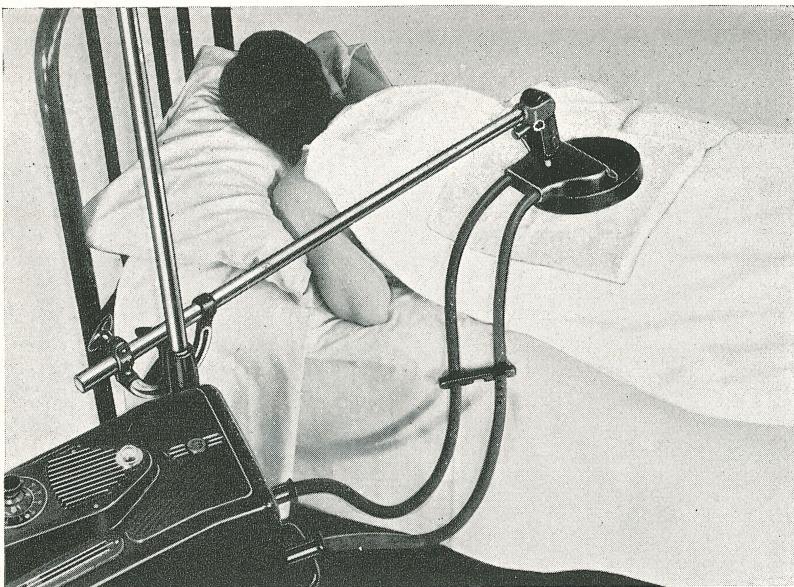


FIGURE 48. Sacro-iliac.

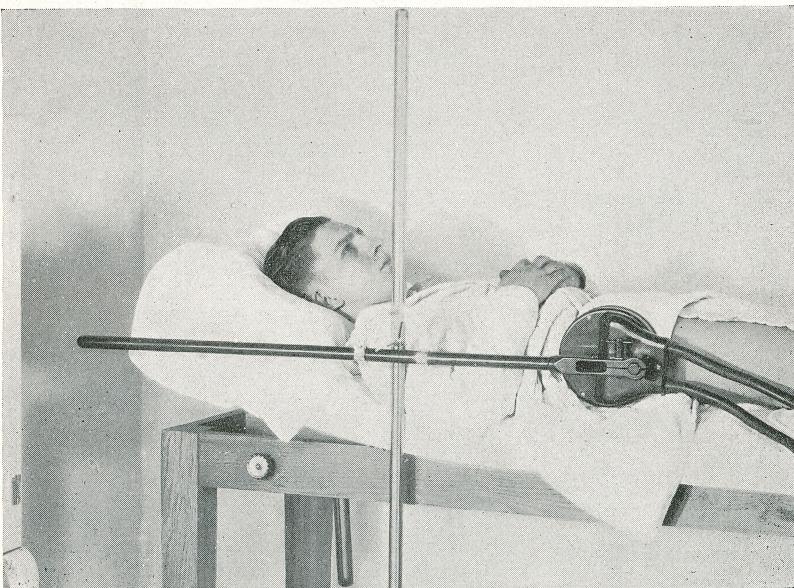


FIGURE 49. Hip.

*Note:* Contact between thighs and scrotum should be prevented by the insertion of a hand towel to prevent arcing and excessive heating due to current concentration.

*Sinus, Eye, Ear, Shoulder, Chest, Sacro-iliac, Hip, and Pelvis (With the Disk Type of Electrode)* (Figures 43, 44, 45, 46, 47, 48, 49, and 50). 1. Place  $1\frac{1}{2}$  inch of bath towelling over the part to be treated.



FIGURE 50. Pelvis.

2. Position the disk electrode as illustrated.
3. Connect the cable terminals to the generator, keeping the two leads separated by a spacer.

**Schmitt's Optimal Dosage Technic.** Believing the practice of giving treatments of twenty to thirty minutes' duration, two, three, or more times per week to all patients, regardless of pathology, was not rational, Schmitt introduced his *Optimal Dosage Technic*. He defines optimal dosage as the smallest power input per unit tissue volume which will establish and maintain an active hyperemia, the application of which must be for such time and must be repeated for such intervals as are necessary to produce a cumulative beneficial effect. Concerning short wave diathermy, he states: "The desired physiologic effect

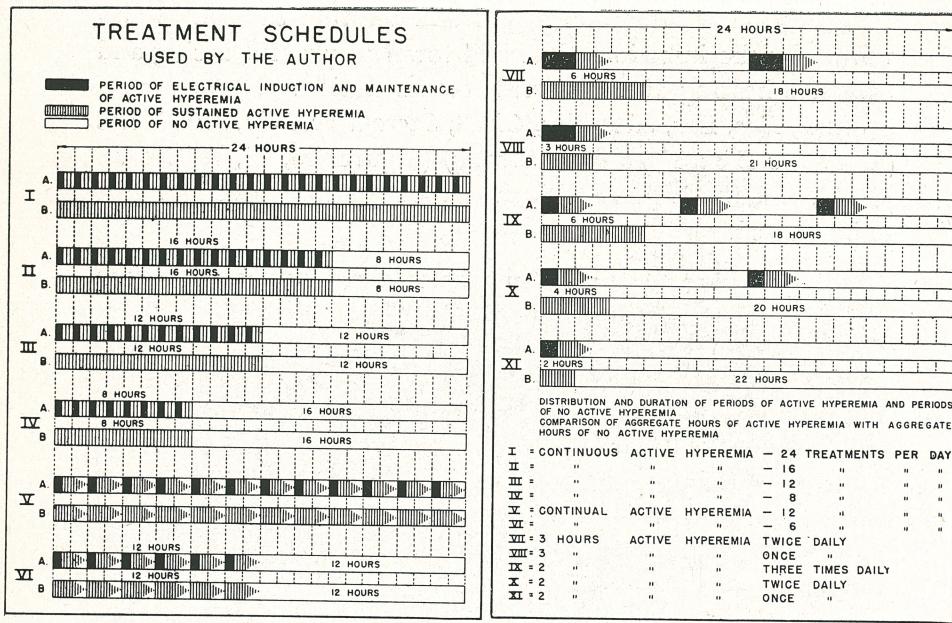


FIGURE 51. Treatment schedules employed by Schmitt.  
(From SCHMITT: *Arch. Phys. Therapy*, 21:716, 1940.)

is the establishment and maintenance of an active hyperemia. The technic . . . is determined by the power input per unit tissue volume, the time of application, and frequency of application."

Schmitt uses the incidence of sweating as the clinical guide for judging the power input per unit tissue volume. The electrodes are so applied that the adjacent, as well as the pathologic, tissues are heated. In addition, the patient is insulated from heat loss. The frequency of treatment, Figure 51, may vary from one to 24, each 24-hour period, according to whether a continuous or an intermittent hyperemia is desired. Such a method of dosage would seem to have a far more scientific basis than the older and prevalent method. Schmitt's method of treatment widens the field of application and increases the effectiveness of an already valuable therapeutic agent.

### Evaluation of the Induction Field Method of Application.

There appear to be no disadvantages in the use of this method of application. On the contrary, its use presents very definite advantages. Such advantages are that heat is generated primarily in the vascular tissues, that the cable can be readily adapted to any part of the body to be treated, and that by means of the induction cable any desired distribution of the power input can be readily achieved. Furthermore, the likelihood of burns and discomfort with this method of application, when properly made, is less than with the electric field method of application.

**Operation of the High Frequency Induction Generator.** In contrast to the operation of the high frequency generator for applying treatment by means of the electric field, the operation of the generator for induction heating is relatively simple. The controls usually consist of an on-and-off switch, an intensity regulator, and on some units a control to tune the patient circuit into resonance with the generator.

The general procedure to be followed in operating such a machine is as follows:

1. Apply the electrode cable or the disk.
2. Connect the cable leads to the proper outlet terminals of the generator, the line switch being in the *off* position.
3. Connect the line cord to a power outlet of the required voltage and frequency. If specified by the manufacturer, connect the machine to a good ground, such as a water pipe or the conduit carrying the electric circuit, if the conduit is continuous, metallic, and thoroughly grounded.
4. Set intensity control at approximately  $\frac{1}{2}$  of the maximum setting.
5. Turn switch to the *on* position, noting whether the unit oscillates.
6. If such control is provided, tune patient circuit into resonance.
7. Adjust the intensity control according to the patient's tolerance, or set it at some point which gives the desired input into

the patient, if an input less than tolerance is to be used (Schmitt technic).

A machine may be so constructed that the cable is part of the oscillating or *tank* circuit of the generator. If there is too close coupling between the coil and the patient, the electrical constants of the circuit may become such that oscillation does not take place. The remedy is obviously a looser coupling, which is achieved by increasing the spacing between the coil and the patient, by decreasing the number of turns in the coil, or by both.

If, in the case of machines which provide for tuning the patient circuit, it is impossible to tune to a condition of resonance, the cable electrode should be reapplied with fewer turns, and possibly with greater spacing between the coil and the patient.

**Dosage.** Dosage in short wave diathermy, using either the electric or the induction field, is the total energy input. It is determined by the rate of input and the time such input is applied as in the case of conventional diathermy. The intensity is that tolerated by the patient or that, as in the case of the Schmitt technic, which is arbitrarily taken as adequate for the effect desired, namely, the production and maintenance of an active hyperemia. The tolerance of the patient and the judgment of the physician as to what would be adequate and yet safe are the only valid guides to intensity. The duration of treatment has been 20 to 30 minutes, repeated two to four times per week. It is our opinion that longer and more frequent treatments would be conducive to better results. Schmitt has found such method of treatment most effective in a wide range of pathology. In Figure 51 are given the duration and frequency of treatment recommended by him.

#### MICROWAVE DIATHERMY

The development of "Radar" was one of the closely guarded war secrets. Radar was made possible by perfection of the "Magnetron" tube. By means of this tube it was possible to generate microwaves. At the end of the war the use of micro-

waves was extended into the field of medicine. The "Microtherm" is the first generator of microwaves to be built for heating human tissues. Knowing the sales appeal to the term "Radar" the manufacturer is, unfortunately, promoting the term "Radar" in connection with the Microtherm generator. The Microtherm is not "Radar" apparatus although a magnetron tube is used. The Microtherm, Figure 52, generates energy

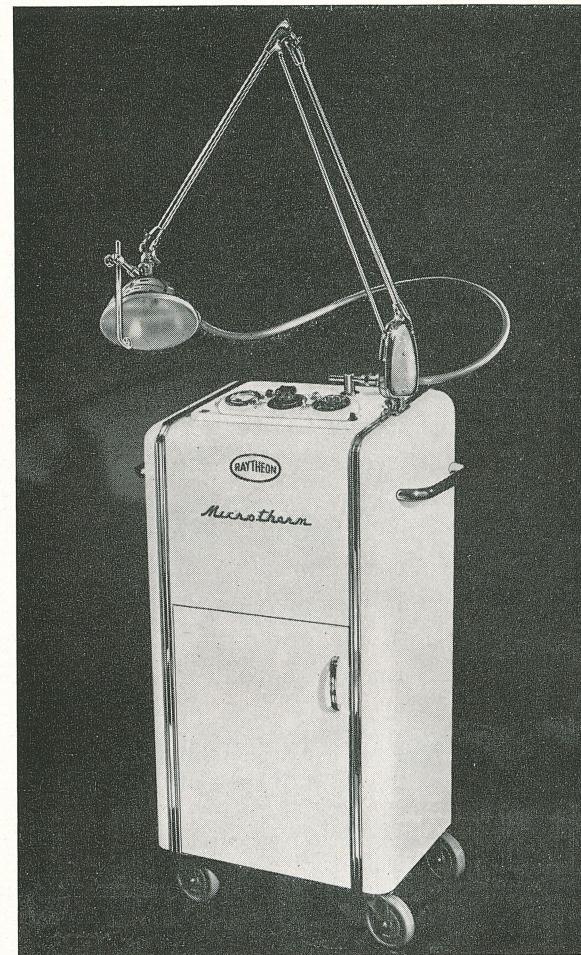


FIGURE 52. The Microtherm. Note spacer attached to the director.

in a *continuous* wave, air cooled magnetron tube, operating at a frequency of 2,400 to 2,500 megacycles per second (2 billion five hundred million cps.) or at a wavelength of approximately 12.2 cms. The generator has a total output of 125 watts. The entire radio-frequency circuit consists of the magnetron oscillating tube with a coaxial cable connected to a director. Microwaves possess optical properties and can be reflected, refracted, diffracted, or focussed. Thus from the hemispherical director energy is reflected and radiated to the tissues to be heated.

The question of ill effects from exposure to microwaves has been investigated by Lidman and Cohen,<sup>3</sup> Daily<sup>4</sup> and Fallis.<sup>5</sup> Lidman and Cohen could find no evidence of stimulation or depression of erythropoietic and leukopoietic systems of army personnel exposed to radiation from standard radar sets for periods ranging from a few months to nine years. Daily studied navy personnel who were exposed for several hours per day for periods up to nine years. He found no hematologic changes, no premature alopecia, no dermatologic manifestations and no clinical evidence of damage to reproductive tissues. Several subjects complained of headaches after exposure to radar waves for several hours. The headaches always disappeared spontaneously within one half to one hour after cessation of exposure. Fallis exposed guinea pigs to radiations from the air-borne unit, SCR-517, which has an output of 45 kilowatts. The animals were exposed for three hours daily for eight weeks at a distance of two feet (60.96 cm.). He noted no effect on appearance, growth, body temperature or reproduction and no histologic changes.

The microtherm unit used in clinical practice has a maximum output of 125 watts. The output of the SCR-517 used by

<sup>3</sup> LIDMAN, B. and COHEN, C.: Effect of radar emanations on the hemopoietic system. *Air Surgeon's Bull.*, 2:448, 1945.

<sup>4</sup> DAILY, L. E.: A clinical study of the results of exposure of laboratory personnel to radar and to high frequency radio. *U.S. Nav. M. Bull.*, 41:1052, 1943.

<sup>5</sup> FALLIS, R. H. JR.: Studies on the biological effect of high frequency radio waves (Radar). *Am. J. Physiol.*, 147:281, 1946.

Fallis is 360 times the maximum output of the microtherm. In view of the evidence produced by these investigators it would seem improbable that any ill effects should result from the limited exposure used in clinical practice.

The heat produced in living animal (dog) tissues by exposure to microwaves has been studied by Krusen, Herrick, Leden and Wakim<sup>6</sup> as well as Osborne and Frederick.<sup>7</sup> Krusen and his co-workers have shown a positive temperature gradient from the skin surface to the deep layer of muscle. Osborne and Frederick, on the other hand, show a negative temperature gradient from the subcutaneous level to a depth of two inches. If radiations of this magnitude produce an increasing temperature from the surface to the deeper layers (positive gradient), a burn could occur in the deeper layers without damage to the surface tissues.

Osborne and Frederick reported heating experiments on the eyes of eight dogs. An average temperature of 105.8° F. was recorded for the vitreous—or a rise of 7.5° F (4.1° C.). They reported there was no evidence of damage. Since then, however, Richardson, Duane and Hines<sup>8</sup> have made a more thorough study of the immediate and delayed effects of microwave irradiations upon the rabbit eye. They confirmed the work of Osborne and Frederick but found that lenticular opacities developed when the vitreous temperature reached or exceeded 45° C. (113° F.). Daily, Wakim, Herrick, and Parkhill<sup>9</sup> have reported similar findings. They exposed the eye of the dog at a distance of three inches or two inches with 75 per cent of the total power output of the generator for a period of 30 minutes. At the three

<sup>6</sup> KRUSEN, F. H.; HERRICK, J. F.; LEDEN, U.; and WAKIM, K. G.: Micromyotherapy: Preliminary report of experimental studies of the heating effect of microwaves (Radar) in living tissues. *Proc. Staff Meet., Mayo Clin.*, 22:209, 1947.

<sup>7</sup> OSBORNE, S. L. and FREDERICK, N. J.: Microwave radiations: Heating of human and animal tissues by means of high frequency current with wavelength of twelve centimeters. *J.A.M.A.*, 137:1036, 1948.

<sup>8</sup> RICHARDSON, A. W.; DUANE, T. D.; and HINES, H. M.: Experimental lenticular opacities produced by microtherm irradiations. *Arch. Phys. Med.*, 29:765, 1949.

<sup>9</sup> DAILY, L. JR.; WAKIM, K. G.; HERRICK, J. F.; and PARKHILL, E. M.: Effects of microwave diathermy on the eye. *Am. J. Physiol.*, 155:432, 1948.

inch distance they reported no clinical pathologic findings were observable. Under these conditions the temperature of the vitreous rose  $3.2^{\circ}$  C. ( $5.8^{\circ}$  F.). But when the director distance was changed from three inches to two inches with the other factors the same, anterior cortical cataract developed within six days after the last exposure. When the power output was in-

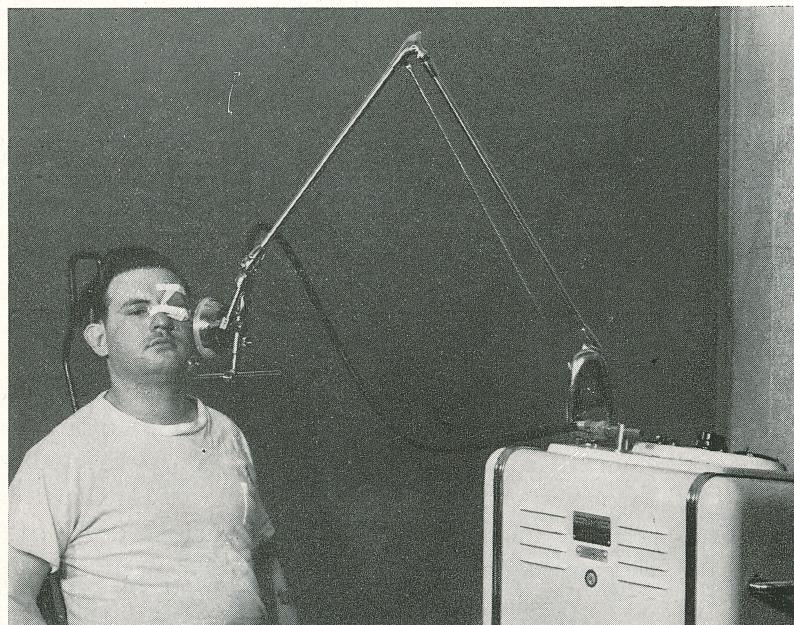


FIGURE 53. Application of microwaves to the maxillary antrum. Note shielding of the eye. (Courtesy Ballenger and Osborne.)

creased to 95 per cent, the director placed at a one inch skin-director distance, and treatment given for 30 minutes, anterior cortical cataracts developed within 24 hours after exposure. It would seem, therefore, from these experiments that one must be extremely cautious in applying microwaves to the eyes if serious damage is to be avoided.

Ballenger and Osborne<sup>10</sup> have studied the value of micro-

<sup>10</sup> BALLINGER, JOHN JR. and OSBORNE, S. L.: Heating of the human maxillary sinus by microwaves. *Arch Otolaryng.*, 51:678, 1950.

waves in heating the maxillary antrum in man. A small but statistically significant temperature rise of  $1.3^{\circ}$  F. was found. To avoid damage to the eye during the 20 minute irradiation these investigators used a metal eye shield to reflect the radiation from this area (Figure 53).

Krusen, Herrick, Leden, and Wakim<sup>11</sup> in their first report presented evidence to show that microwaves would not only produce heat in tissues but also produced a marked and significant increase in blood flow as measured by the "bubble flow meter."

Since then Kemp, Paul, and Hines<sup>12</sup> compared the effects of short wave and microwave heating on blood flow through either the femoral vein or femoral artery of anesthetized dogs. Their measurements were made with the "bubble flow meter." They found that microwave heating consistently caused a significant increase in blood flow. On the other hand, when short wave diathermy was used to produce a comparable temperature rise in the muscles, blood flow was not increased but was frequently associated with a diminished blood flow. As a result Kemp, Paul, and Hines seriously questioned whether the beneficial effects of short wave diathermy are due to vascular changes in the deep tissues. It is probable, however, that minor changes in blood flow to a local area of an extremity may not be accurately reflected in the blood flow in a large artery owing to the presence of reciprocal vascular changes in the same extremity.

About the same time, Wise,<sup>13</sup> using short wave diathermy as the heating agent, measured blood flow in the forearm of ten normal subjects by means of the venous occlusion plethysmograph. Treatment was given in accordance with acceptable clin-

<sup>11</sup> KRUSEN, F. H.; HERRICK, J. F.; LEDEN, U. L.; and WAKIM, K. G.: Microkymatherapy preliminary report on experimental studies of the heating effect of microwaves (Radar) in living tissues. *Proc. Staff Meet., Mayo Clin.*, 22:209, 1947.

<sup>12</sup> KEMP, C. R.; PAUL, W. D.; and HINES, H. M.: Studies concerning the effect of deep tissue heat on blood flow. *Arch. Phys. Med.*, 29:12, 1948.

<sup>13</sup> WISE, CHARLES S.: The effect of diathermy on blood flow plethysmographic studies. *Arch. Phys. Med.*, 29:17, 1948.

ical practise. In all experiments Wise found a definite increase in blood flow during the period of short wave heating.

In a similar study using short wave diathermy, Wakim, Gersten, Herrick, Elkins, and Krusen<sup>14</sup> obtained a substantial increase of blood flow on both animals and man. They measured blood flow with the "bubble flow meter" in animals and for man a more refined venous occlusion plethysmograph than that used by Wise. Furthermore, they showed that when an area of the body was heated at some distance from the site of blood flow measurement, a significant augmentation of blood flow occurred. This increase, however, was not as marked as when diathermy was applied directly to the extremity under measurement.

A comparative study of short wave and microwave diathermy on blood flow on dogs was made by Siems, Kosman, and Osborne.<sup>15</sup> Blood flow measurements were made with the "bubble flow meter" modified from the design used by Krusen and co-workers. Siems concluded that short wave and microwave diathermy were equally effective in producing increased blood flow in the extremities of normal dogs.

From the evidence presented one must conclude that both microwaves and short wave diathermy are equally effective in increasing blood flow. Examination of the data of Kemp, Paul, and Hines leads one to suspect that the extremities of the animals treated with short wave diathermy were initially in a state of vasodilation which probably masked any vascular response to heating. This could account for the negative results obtained with short wave diathermy.

Studies of deep circulatory response to short wave diathermy and microwave diathermy in man were undertaken by Kottke,

<sup>14</sup> WAKIM, K. G.; GERSTEN, J. W.; HERRICK, J. F.; ELKINS, E. C.; and KRUSEN, F. H.: The effects of diathermy on the flow of blood in the extremities. An experimental and clinical study. *Arch. Phys. Med.*, 29:583, 1948.

<sup>15</sup> SIEMS, L. L., KOSMAN, A. J.; and OSBORNE, S. L.: A comparative study of short wave and microwave diathermy on blood flow. The role of the somatic and sympathetic nerves in the vascular response to deep tissue heating. *Arch. Phys. Med.*, 29:759, 1948.

Koza, Kubicek, and Olson.<sup>16</sup> Blood flow in seven young adult male subjects was measured by renal plasma flow and glomerular filtration after diathermy was applied to the region of the kidney. They found both types of heating caused a significant decrease of renal plasma flow and glomerular filtration without significant changes of blood pressure, and concluded that in as far as renal blood flow may represent the deep circulation, diathermy heating causes a decrease in deep blood flow. Kottke and co-workers stated these results might be due to the fact that when large amounts of heat are applied to the body, the predominant reflexes are concerned with dissipation of heat from the body. Cutaneous vasodilatation occurs with flushing, sweating, and increased skin temperature increasing the rate of heat loss from the body surface. To maintain the blood pressure in the face of this increased peripheral circulation cardiovascular readjustments are necessary. The pulse rate and cardiac output increase. Vasoconstriction occurs in the vascular beds not concerned with heat loss such as the splanchnic and renal beds. It is an attempt of the body to maintain internal homeostasis.

Imig, Thomsen, and Hines<sup>17</sup> studied the effects of microwave and infrared irradiations on the testicular tissue of rats. The temperature at the center of the testes was elevated at levels from 34° to 47° C. The temperature was then maintained for periods varying from 5, 10, or 15 minutes. In every instance testicular degeneration resulted when the temperature of the testes reached 35° C. as the result of a single ten minute exposure to microwave irradiation. In some instances they reported testicular damage resulted from a single exposure at temperatures between 30° and 35° C. On the other hand when infrared irradiation was applied for 10 minutes with a testicular temperature of 38° C. they found no evidence of damage. With infra-

<sup>16</sup> KOTTKE, F. J.; KOZA, D. W.; KUBICEK, W. F.; and OLSEN, M.: Studies of deep circulatory response to short wave diathermy and microwave diathermy in man. *Arch. Phys. Med.*, 30:431, 1949.

<sup>17</sup> IMIG, C. J.; THOMSEN, J. D.; and HINES, H. M.: Testicular degeneration as a result of microwave irradiations. *Proc. Soc. Exper. Biol. & Med.*, 69:382, 1948.

red, degeneration, they state, was not found unless a temperature of 40° C. or higher was secured. They suggest that the observed damage from microwaves might result in part from other factors than heat. Furthermore, they stated, perhaps precautions, such as wearing a shield, should be taken by those giving treatment with microwave generators. However, it would seem unlikely that therapists giving treatment would absorb sufficient radiation to produce such temperatures in the center of the testes. Patients receiving treatment in the region of the testes might need some consideration but this is not likely.

With a special technic, Oldendorf<sup>18</sup> utilized microwave radiation for the artificial production of focal neurological lesions. Focal lesions were produced in rabbit brains without surgical procedure. Moreover, the site of the cortical lesion was accurately determined before the irradiation. Further work to improve technic is in progress for this rather intriguing work. It is hoped to eventually allow penetration in an area of any shape and in a larger area. This work holds a great deal of promise in both experimental and clinical neurology.

Worden, Herrick, Wakim, and Krusen<sup>19</sup> made a comparative study before and after exposure to microwaves of the temperatures of the skin, subcutaneous tissue, superficial muscle, and deep muscle of the thigh of the dog with the circulation intact and after ischemia was produced by clamping the abdominal aorta. Temperatures were measured after exposures of 5, 10, 15, or 20 minutes duration. The temperature rise in the ischemic tissues was found to be slightly higher than in normal tissues but was not considered significant after 5 or 10 minutes of exposure, nor was any evidence of burning found after exposure for these shorter periods. After 15 to 20 minutes of exposure, the increased temperatures in ischemic tissues were considered significant, and out of 11 experiments made after exposure for

<sup>18</sup> OLDDENDORF, W. H.: Focal neurological lesions produced by microwave irradiation. *Proc. Soc. Exper. Biol. & Med.*, 72:432, 1949.

<sup>19</sup> WORDEN, R. E.; HERRICK, J. F.; WAKIM, K. G.; and KRUSEN, F. H.: The heating effects of microwaves with and without ischemia. *Arch. Phys. Med.*, 29:751, 1948.

these longer periods, gross evidence of burning was noted in 10. In some instances burns occurred at temperatures that were lower than those seen after exposure of tissues with intact circulation in which no burning occurred. Therefore, temperatures tolerated by normal tissues cannot be regarded as the safe range of tolerance for ischemic tissues. Bony prominences were also found to be potential sites for formation of blebs. Another aspect of this investigation was to determine the optimal duration of exposure to microwaves. A 20 minute exposure was found to be the most efficient giving maximal heating.

Most clinicians have advised against using high frequency current in any region of the body having metal implants directly beneath the surface to safeguard against heating of the metal to a degree that contiguous tissues might be severely damaged. Whether this danger is real has not been satisfactorily answered. In 1947 Lion<sup>20</sup> demonstrated *in vitro* the field-concentrating effect of tantalum when immersed in electrolytes and irradiated with frequencies of 10 to 55 megacycles. He also showed it is possible to coagulate solutions of egg albumin at the points of field concentration. In the same year Etter, Pudenz, and Gersh<sup>21</sup> implanted metals—such as are used in surgery—in animals and then exposed them to radiations of wavelengths of 8 and 24 meters. From their histological studies they concluded, that, in the intact animal, destruction from heating did not occur in the tissues contiguous to the implanted metals. The metal implants were imbedded between 0.5 to 1.0 cm. below the skin surface.

A more recent study is that of Feucht, Richardson, and Hines<sup>22</sup> who studied the effects of implanted metals on tissue heating produced by microwaves. They first secured a pattern

<sup>20</sup> LION, K. S.: The effect of the presence of metals in tissue subjected to diathermy treatment. *Arch. Phys. Med.*, 28:345, 1947.

<sup>21</sup> ETTER, H. S.; PUDENZ, R. H.; and GERSH, I.: The effects of diathermy on tissues to implanted surgical metals. *Arch. Phys. Med.*, 28:333, 1947.

<sup>22</sup> FEUCHT, B. L.; RICHARDSON, A. W.; and HINES, H. M.: Effects of implanted metals on tissue hyperthermia produced by microwaves. *Arch. Phys. Med.*, 30:164, 1949.

of temperature increases by radiating blocks of fresh beef liver with metal implants. As a result they implanted a 6 by 6 cm. stainless steel plate at a depth of 0.5 cm. under the abdominal wall and peritoneum of live rabbits. The area holding the implant was irradiated for a period of ten minutes with an output from the microtherm of 62.5 watts. The temperature increase was found to be significantly greater than that of the control area both at the cutaneous level and above the plate. Under the plate the temperature increase was significantly greater than the control. The authors state the tissue over the plate was usually edematous and appeared to be coagulated after irradiation. While edema was present on the control side of some of the irradiated rabbits it was less severe than in the side with the stainless steel implant. It is also noteworthy that they found the greatest temperature rise at the cutaneous level, the increase diminishing with depth. They explained the extremely high temperatures occurring in the tissues with the metal implants on the basis of the reflected standing wave theory. Heating of the steel plate they believed accounted for the high temperatures found behind the plate. In their conclusion these workers state, "that, with careful use it seems likely that during microwave irradiation there is little danger of burning a patient who either had metal implanted or metal imbedded in tissue. In most instances the metal is not as large or as close to the surface as described in this report. However, the physical therapist should be cautious in the application of microwave diathermy to tissue containing metal implants." Nevertheless, until such technics are known definitely to be harmless, it would seem wise to avoid irradiating any area in which metal might be imbedded.

The tissue heating gradient with short wave diathermy is such that the heat is greatest in the superficial tissues and becomes less and less with increasing depth. This favorable ratio of skin dose to depth dose has been a valuable safety factor, particularly, as surface sensation is the only safe guide for dosage.

According to Krusen, Herrick, Leden, and Wakim,<sup>23</sup> Gersten, Wakim, Herrick, and Krusen,<sup>24</sup> and McRae, Herrick, Wakim, and Krusen<sup>25</sup> irradiation by means of microwaves reverses this heating gradient so that the temperature of the muscle is greater than that of the skin and subcutaneous tissues following a 20 to 30 minute exposure. If irradiations of this magnitude produce an increasing temperature from the surface to the deeper layers, a burn could occur in the deeper layers although the surface is quite unharmed.

On the other hand Osborne and Frederick<sup>26</sup> reported in their investigation with microwave irradiation the highest temperatures were found in the superficial tissues. The temperature of the tissues gradually decreased with increasing depth so that the lowest temperature was found consistently in the muscles at a depth of two inches. The temperature gradient, however, was not as steep as in the short wave diathermy. In two of their experiments the animal received burns. The burned areas sloughed to a depth of approximately one half inch five days later and the lesion required six weeks to heal. This would seem to substantiate the heating gradient found by their temperature measurements.

Feucht, Richardson, and Hines,<sup>22</sup> in their investigation with microwaves confirmed the work of Osborne and Frederick. Feucht found the greatest temperature increase was at the cutaneous level, the temperature decreasing with increasing depth.

It is difficult to account for these divergent views. Perhaps, too, these differences reported are more apparent than real.

<sup>23</sup> KRUSEN, F. H.; HERRICK, J. F.; and LEDEN, W.: Microkymatotherapy. *Proc. Staff Meet. Mayo Clinic*, 22:209, 1947.

<sup>24</sup> GERSTEN, J. D.; WAKIM, K. G.; HERRICK, J. F.; and KRUSEN, F. H.: The effect of microwave diathermy on the peripheral circulation and on temperature tissue in man. *Arch. Phys. Med.*, 30:7, 1949.

<sup>25</sup> MCRAE, J. D.; HERRICK, J. F.; WAKIM, K. G.; and KRUSEN, F. H.: A comparative study of the temperatures produced by microwave and short wave diathermy. *Arch. Phys. Med.*, 30:199, 1949.

<sup>26</sup> OSBORNE, S. L. and FREDERICK, J. N.: Microwave radiations. *J.A.M.A.*, 137: 1036, 1948.

While the methods used by both groups are essentially the same, some differences are evident and may account for the variations. For instance, Osborne and Frederick measured the tissue temperatures at a depth of 1.27, 2.54, 3.81, and 5.08 cm. They did not record skin temperatures because they considered them unreliable. Krusen and associates on the other hand took measurements on the skin surface, in the subcutaneous tissue, and in the muscle either at a depth of 1.53 or 3 cm. Osborne and Frederick report the temperature differences between these levels showed more variation among individual experiments than did the differences between 2.54 and 5.08 cm. levels. To demonstrate the effect of a strong breeze on the temperature readings at these levels they exposed an animal to the air currents from an open window. The final temperature showed an increase from the subcutaneous level of 100.8° F. to 107.1° F. at a depth of 2.54 cms., demonstrating a positive heating gradient shown by Krusen and co-workers. The experiment was repeated on the same animal, but protected from the breeze, and the final temperatures showed the usual negative heating gradient.

Krusen and co-workers state the temperature readings were recorded at minute intervals one minute after the cessation of heating. McRae is the exception. He states they made simultaneous readings which were photographically recorded. The order of taking the readings by Krusen and his co-workers is not stated. This must be of considerable importance because heat is more readily dissipated from the more superficial tissues. Osborne and Frederick recorded their temperature in the following order: 1.27, 2.54, 3.54, and 5.08 cm. They state the first reading was taken within 20 seconds after cessation of heating. If a considerable period of time elapses before the superficial tissues are recorded, most of the heat will have been dissipated and so speed is of considerable importance.

The heating gradient is of considerable importance to the clinician because if the usual *heating* gradient is *reversed*, then microwave heating could prove to be extremely dangerous. It certainly would seem proper to guard a patient during micro-

wave radiation from drafts of air that might cause surface cooling. The heating gradient with these radiations is less steep than any other form of diathermy and this accounts for the lack of discomfort during treatment. Our own experimental and clinical investigation led us to believe that when proper care and good clinical judgment is used little damage will result from use of the Microtherm.

A disadvantage of this method of tissue heating is its definite localization. There has been a gradually growing appreciation that diathermy is more effective when large areas, such as an entire limb, are heated rather than a definite localized area. By this large area technic the circulation of an entire limb can be influenced, and if dosage of radiation is low, an active hyperemia is secured and passive congestion avoided. At present, it is not possible to heat large areas of the body with the Microtherm because of the limited size and shape of the directors in use. This would seem to be a distinct disadvantage.

Microwave treatment should be applied cautiously because the minimum of erythema and discomfort to the patient gives the operator less warning of overheating.

**Technic of Application.** The electrical circuits of the Microtherm include a full-wave rectifier, fully filtered, using separate plate and filament transformers. The input to the high-voltage transformer is controlled by a time-delay relay, an interval timer, and a variable auto-transformer. The last named provides for adjustment to various line voltages and controls the power output of the continuous-wave magnetron. The power level is indicated on a milliammeter which is calibrated in PERCENTAGE OF POWER OUTPUT. A motor-driven blower supplies cooling air throughout the interior of the unit. Preheat and Power Switches turn the filament and plate voltages on or off. Accompanying lights indicate switch positions. The output of the magnetron is carried to the front panel where it is made available for application to the patient by means of a coaxial cable and director.

There is no direct radiation from this cable as the outer conductor or shield reflects all energy back into the cable. All radia-

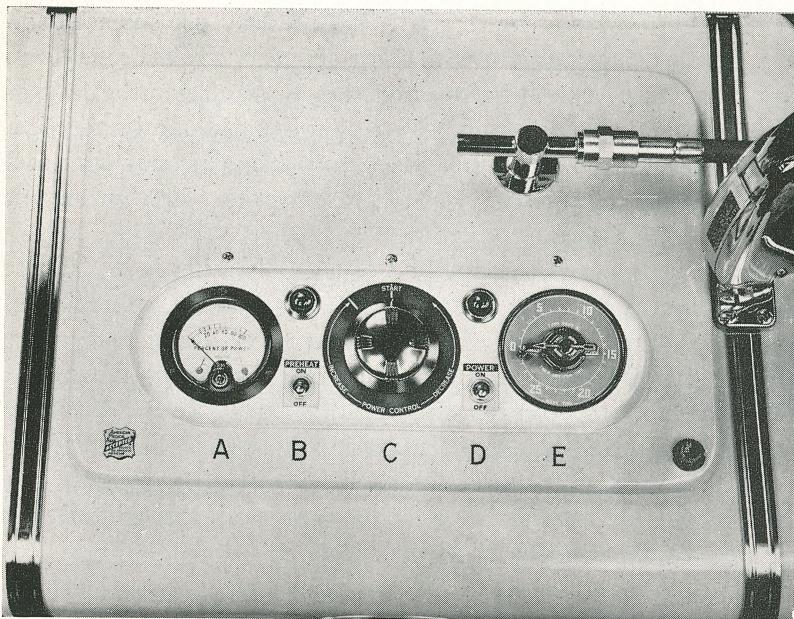


FIGURE 54. Microtherm Control panel: A, Power output; B, Preheat switch; C, Power Control; D, Power Switch; E, Mark Time treatment Timer.

tion takes place from the director.

**Operation.** The components of the control panel are shown in Figure 54. To place the Microtherm in operation, proceed as follows:

- Make sure that the switches marked PREHEAT and POWER are in the "Off" position.
- Insert the plug of the line cord into a suitable 115-volt a.c. electrical outlet.
- There is a ground wire on the a.c. cord with a removable threaded plug on the end. Withdraw a screw from the a.c. outlet plate and replace with the threaded plug. Connect the ground wire to the threaded plug. Grounding of the unit is in accordance with safe practice and the Underwriter's requirements.
- Place the PREHEAT Switch in the "On" position. The green indicator light will glow and the blower will begin to

circulate air throughout the unit. The time-delay relay will begin operation and will close the circuit to the Interval Timer and POWER Switches in three minutes. The time delay allows the magnetron to heat to the required temperature before power is applied, thus protecting the tube and prolonging its life. Unless the blower operates when the PREHEAT Switch is turned on, the unit should be shut off immediately. Operation without the blower will result in excessive heating and irreparable damage to the magnetron. Normal operation can be determined by listening to the blower and by checking the flow of air. Slow and spasmodic operation indicates an abnormal condition. Be sure that the air intake (in rear of control panel) and outlet are uncovered at all times.

(e) When the red light glows, set the Interval Timer for the desired treatment period. The red light merely indicates that the unit is ready to be turned on. The meter indicates that it is actually operating. No output can be obtained when the Interval Timer is at zero. It must be turned on through the three-minute marker before the switch closes.

(f) Turn the POWER Switch to the "On" position. The unit is now in operation.

(g) Turn the Power Control (center of panel, Figure 54c), clockwise until the desired output is reached, as indicated on the meter.

The power level may be varied at any time and can be read on the meter. While it is possible to turn the unit on with the power output set at any level, it is recommended practice to return the Power Control to a low but readable level after treatment. If, after the power has been turned on and the control advanced, the power level suddenly drops, the control should be turned back to zero and again advanced.

(h) If a succession of treatments are to be given, the unit may be left in a standby condition with either or both the Internal Timer and the POWER Switches in the "Off" position. If the PREHEAT Switch is turned off, it will again be necessary to wait three minutes for the time-delay relay to close.

(i) When turning off the unit, *always* turn off both the PRE-HEAT and the POWER Switches.

Three different directors are supplied (Figure 55). The characteristics of these are given below with diagrams of the surface heat or energy patterns. These patterns have been taken in dead tissue and do not reflect the levelling effect of the circulatory system of live tissue.

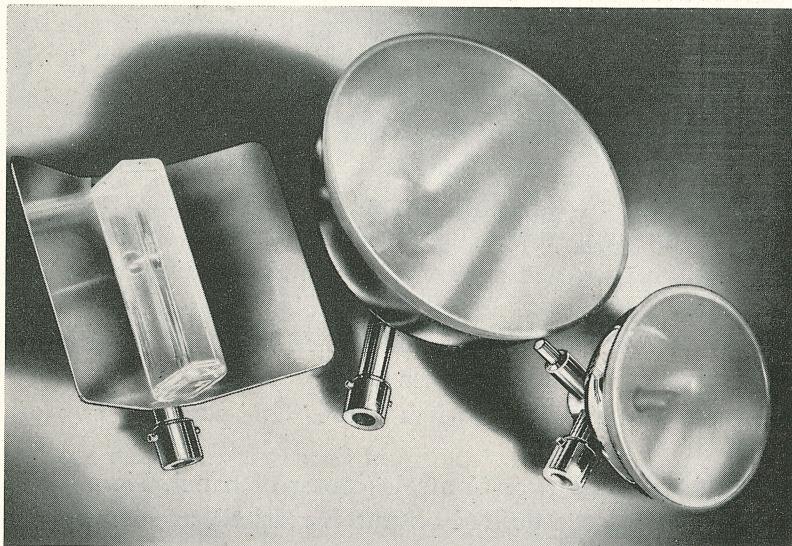


FIGURE 55. Types of Directors used for the application of microwaves to the patient. Reading left to right: Directors A, B, and C.

**Director A.** This is a four inch hemisphere type. It is suitable for general use on areas up to six inches in diameter. The surface heat pattern produced with this director, when spaced two inches from the skin, is shown in Figure 56. Note that the temperature at the center of the pattern drops to 50 per cent of that at peak levels. The director should be centered over the protruding part of the body whenever possible. Spacings closer than one inch are not recommended as the efficiency of energy transfer deteriorates, cooling of the skin becomes restricted, and it is difficult to observe skin conditions. Spacings greater than two

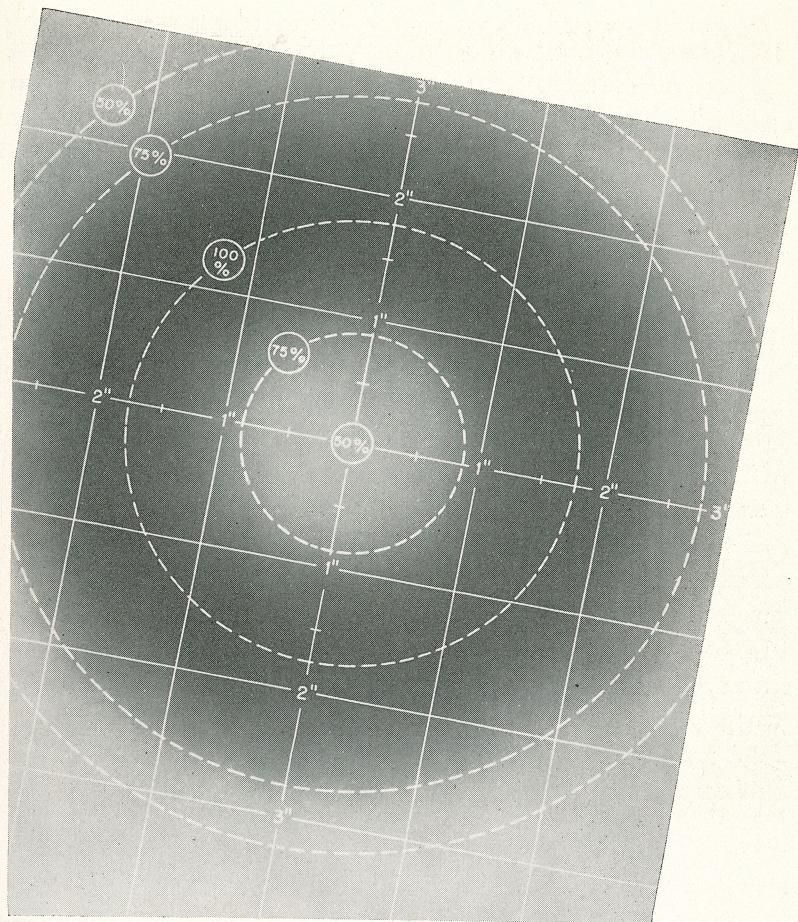


FIGURE 56. Surface heating pattern in dead tissue with Director A placed two inches from the surface of the skin.

inches are permissible but the area serviced does not increase appreciably and heat becomes inadequate even at full power.

**Director B.** This is the six inch hemisphere type. It is particularly well suited for the treatment of large joints such as the knee, shoulder, or elbow.

The sizable low heat area in the center provides a relatively even distribution of heat over an irregular surface such as the

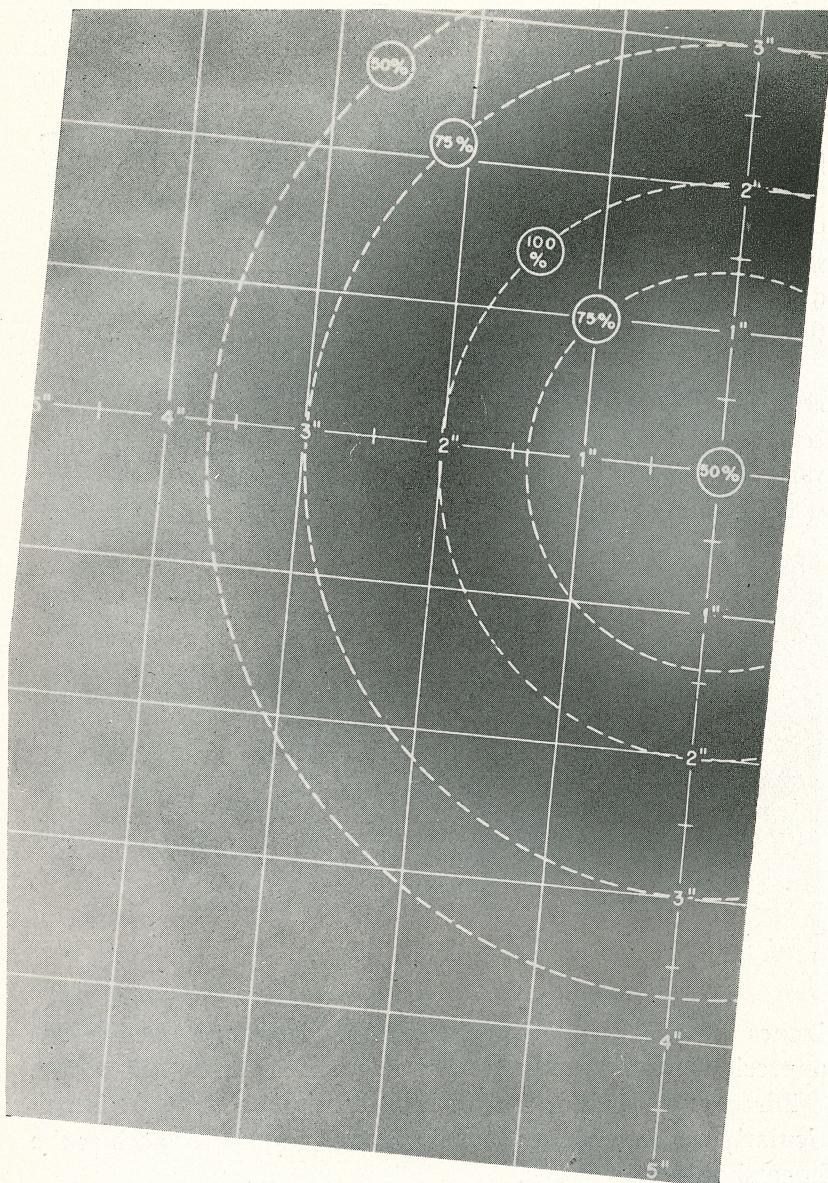


FIGURE 57. Surface heating pattern of Director B (6 inch hemisphere) placed two inches from skin.

shoulder. This director can be spaced between two and four inches from the skin surface. It should not be spaced closer than two inches as efficiency (and consequent penetration) drops off very rapidly. The four inch spacing provides only sufficient power for low heating. At any spacing in excess of four inches, power level becomes too low to be of value. The surface heat pattern is indicated in Figure 57. This director at three inch spacing is effective over an area approximately  $8\frac{1}{4}$  inches in diameter. This area, of course, includes the subnormal level in the center, as previously noted.

**Director C.** This is the corner reflector type, provided to treat relatively smooth or concave body contours. Note that the heat reaches a maximum at the center of the pattern (Figure 58). By varying the spacing between the edges of the reflector and the skin, it is possible to vary considerably the area covered.

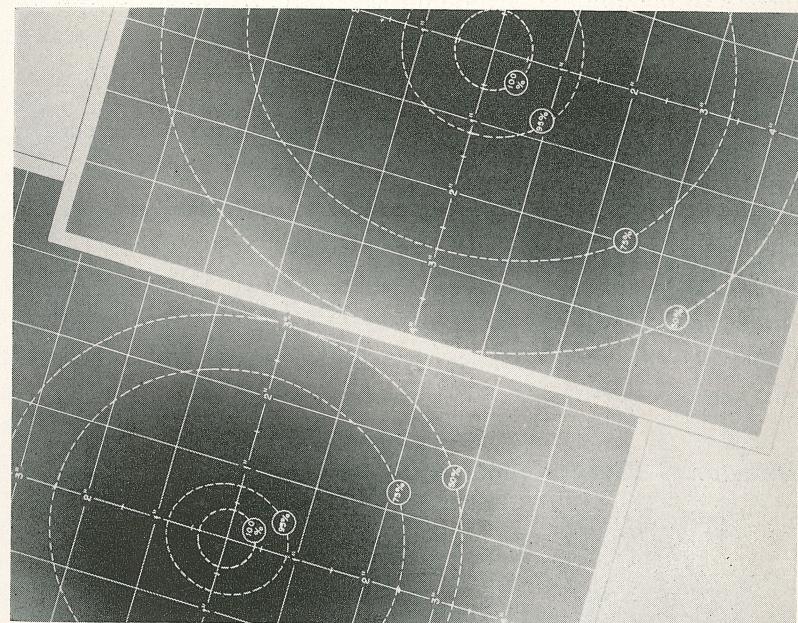


FIGURE 58. Surface heating pattern in dead tissue of Director C—corner reflector type. Lower pattern two inch skin-director distance. Upper pattern three inch skin-director distance.

**Treatment.** The area to be treated, the location of the site in the body, and the nature of the surface should determine the selection of the proper director. The recommended spacings between the director and the body should be followed as closely as possible.

In general it should be remembered:

- (1) As spacing is increased, the area serviced increases.
- (2) As spacing or area serviced is increased, the power required will increase.

The determination of power output and the length of treatment are matters for the judgment and experience of the clinician. Experience to date suggests that, initially, treatments should be at least 20 to 30 minutes in length.

Power output varies with the size and nature of the director. For *initial use*, the following output ranges (meter readings) are suggested for moderate to high heat in the treatment of normal individuals for periods of 15 to 20 minutes:

*Director A* (4 in. hemisphere)

<i>Spacing</i>	<i>Meter Reading</i> (per cent)
1 in.	30-40
2 in.	50-60

*Director B* (6 in. hemisphere)

<i>Spacing</i>	<i>Meter Reading</i> (per cent)
2 in.	40-50
3 in.	60-80
4 in.	100

*Director C* (Corner reflector)

<i>Spacing</i>	<i>Meter Reading</i> (per cent)
1 in.	15-20
2 in.	20-30
3 in.	60-70
4 in.	70-80
5 in.	90-100

For convenience, a spacer is used. This spacer (Figure 52) fits on the back of the directors and opposite to the cable connection. The plastic rod should be set with the desired spacing appearing opposite the edge of directors A and B. In case of director C, the outside of the plastic radiator cover is the measuring point. In many applications, this spacer will assist the patient in maintaining proper position of the director.

All clothing should be removed from the area to be treated. It is permissible to wipe the skin with towelling during treatment if perspiration develops.

(1) The unit should be properly grounded at all times. When grounded, the operator is completely protected against injury.

(2) Surfaces to be treated should be dry.

(3) Metal objects should be removed from the body area to be treated.

(4) Power output should not exceed surface tolerance of the patient.

(5) The patient may be treated when on a metal chair or table; but if a thin portion of the body such as a hand is treated when supported by the metal, lower power output should be used. Reflection of energy from the metal will increase the amount of energy applied to the hand.

(6) The directors should not be operated without their protective covers, as burns may be sustained if contact is made with the radiators. These covers can be quickly replaced. When power is on, directors should not be placed with the open side against a metal surface such as a table. To do so will cause irreparable damage to the magnetron tube.

## V

## CONTRAINDICATIONS FOR ALL TYPES OF DIATHERMY APPLICATION

THERE are actually very few contraindications to the use of diathermy. However, it has been generally agreed that its employment is contraindicated in the following conditions:

1. Acute inflammatory processes accompanied by fever and non-draining suppuration, such as otitis media, appendicular abscess, and acute pelvic infections.
2. A tendency to hemorrhage. Diathermy should never be applied to patients having recent hemoptysis, bleeding gastric ulcers, large varicose veins, or during the period of pregnancy.
3. Menstruation. Diathermy should not be given through the pelvis during such period.
4. Edema. Concerning edema as a contraindication, Schmitt states: "It is well to recognize that in our chief indication for diathermy, namely, inflammation, we find edema to be our *chief contraindication*. The severity of the edema is always a definite but also a relative contraindication."
6. Peripheral nerve lesions. In the United States it has been generally considered inadvisable to subject such lesions to treatment by high frequency because of the possibility of associated anesthesia. However, work by Bauwens<sup>1</sup> leads him to conclude:

"Provided the circulation in a paralyzed limb is capable of being accelerated, a rise in temperature and efforts to keep this near to the normal constantly are indicated, in order to promote repair, facilitate movement and increase excitability.

"This is best achieved by warming the limb in the ultra high frequency field provided by coil electrodes. Other methods are available and their efficacy is a function of their capacity to enable heat to reach deep structures without steep temperature

<sup>1</sup> BAUWENS, P.: Heat and electricity in the treatment of nerve lesions. *Brit. J. Phys. Med.*, 5:48, 1942.

gradients, which are hazardous in the presence of anesthesia. These provisos are not adequately satisfied with methods employing radiant heat or classical diathermy. It is not enough to warm merely the affected or cold part of a limb; as much as possible of the portion above the level should be treated so as to enhance the circulation generally. Between treatments, which should be given twice daily, every effort should be made to prevent heat losses from limbs by encasing them in sleeves or muffs made of heat-insulating materials and padded after the fashion of tea cosies."

## VI

### THE DIATHERMY PRESCRIPTION

#### A. CONVENTIONAL DIATHERMY

1. Region to be treated, e.g. .... Sacro-iliac
2. Technic of application .... Transverse
3. Electrodes .... Contact metal plates
4. Current intensity .... Tolerance
5. Time .... 30 minutes
6. Frequency .... Daily

#### B. SHORT WAVE DIATHERMY

1. Region to be treated, e.g. .... Knee
2. Technic and application of electrodes
  - a. Transverse pads applied to lateral surfaces of knee.
  - b. Double cuffs.
  - c. Air spaced; equally spaced on anterior surface, one above and one below patella, six inches between centers.
  - d. Inductance cable; encircling the knee, with three turns,  $2\frac{1}{2}$  to 3 inches apart.
3. Wavelength .... 6, 12, 18, or 24 meters
4. Spacing ....  $\frac{3}{4}$  to 1 inch
5. Intensity .... Tolerance
6. Time .... 30 minutes
7. Frequency of treatment .... 3 times weekly

#### C. MICROWAVE DIATHERMY

1. Region to be treated, e.g. .... Sacro-iliac
2. Director .... B
3. Skin-Director distance .... 2" (?)
4. Power output .... 60% (?)
5. Time .... 20 minutes
6. Frequency .... Daily

### THERAPEUTIC USES

#### CLAIMS OTHER THAN HEAT MADE FOR SHORT WAVE DIATHERMY

The widely employed term *short wave therapy*, with qualifying wavelength to designate the therapeutic application of high frequency fields and currents of various frequencies, is unfortunate in that it connotes we are dealing with a form of radiant energy of various wavelengths capable of producing specific effects as in the case of x-rays and ultraviolet and infrared radiation. This is confusing and has led many to assume that, as with radiation, specific effects should be obtainable.

Many effects have been claimed for short wave diathermy, some well-established and others which must still be considered speculative. The literature on the subject contains much that deals with thermic effects. In addition much discussion and experimental work has been published on types of reactions which appear without simultaneous measurable temperature rise.

The importance to a physician of a knowledge of the effects of high frequency fields and of the probable mechanism by which such effects are brought about, cannot be too greatly stressed. Rational therapeutic application should be based on such knowledge.

The effects claimed for short wave diathermy are thermal, electrical, bactericidal, and biologic. Other effects, possibly of a chemical nature, have also been claimed. The primary effects of high frequency fields are probably thermal and electrical. All phenomena should, if possible, be explained in terms of generally accepted physical and chemical laws before attributing such phenomena to some assumed and mysterious effect of the causative agent.

After giving careful consideration to the evidence presented in the literature in support of the various effects claimed for short wave diathermy, it is my opinion that much of the disagreement is more apparent than real for the following reasons:

1. That many investigators either fail to recognize the difference between heat generation in tissues and the rise in tem-

perature, or, if they do appreciate the difference, do not make that fact sufficiently evident.

2. That, if no temperature can be measured, the assumption is made that no heat is being generated.

3. That laboratory experimenters only too frequently fail to maintain constant all variables except those which are to be compared.

4. That clinical investigators and others who, by the conditions of the experiments, are unable to maintain all variables constant except those between which a relationship is to be determined, fail to accumulate sufficient data for statistical interpretation.

5. That, in attempting to duplicate the experiments of others, investigators have not always duplicated all conditions of the experiments with the result that data are obtained apparently disproving the point in question.

Although in my opinion, based on available evidence, all observed therapeutic effects can be explained on the basis of heat generation, with or without measurable temperature increment, we fully realize that further experimentation may present evidence substantiating claims which today are speculative. However, until the proponents of such claims have presented experimental evidence which can be duplicated by others, physicians should base the application of short wave diathermy solely on effects which are at present well-established.

#### CLINICAL APPLICATIONS

It is difficult to discuss fully in a small monograph such as this, all the therapeutic uses of diathermy. The task becomes doubly difficult when one considers that diathermy is usually but one of several measures employed in a treatment. The discussion, therefore, will be confined to its more apparent uses leaving the reader to consult treatises dealing adequately with the subject of physical medicine in its entirety. As a generalization one can state that when it is therapeutically desirable to produce a marked elevation of temperature in tissues lying

deeply below the surface of the body, diathermy is an indicated procedure. The circulation of the blood and lymph flow is increased by diathermy and the resultant active hyperemia should be of marked therapeutic value. In this respect blood flow is just as effectively increased by either conventional, short wave, or microwave diathermy. The extent of the increased blood flow is dependent on the temperature of the heated tissues. Siems, Kosman, and Osborne<sup>1</sup> have reported, however, that heat does not increase blood flow in the limb of dogs with an experimentally produced peripheral nerve lesion. This is the first time evidence has been given to demonstrate the possible role of the sympathetic nerves in the reaction to local heating. Thus the rationale of heat applications in the treatment of patients with peripheral nerve lesions is open to question. These investigators further concluded there is no evidence that any known method of heating possesses properties which have any specific effect on blood flow. No procedure effective for good can be devoid of all possibilities for harm. The essential consideration is one of dosage.

In normal animal structures, great intensities of current will cause local stasis of circulation and tissue death, while milder concentrations will produce an active hyperemia and increased local metabolism. In pathologic states, where the circulation may be relatively inadequate, the margin of safety between intensities of current capable of causing beneficial or harmful effects becomes much smaller. The fact that there is no appreciable rise in temperature does not nullify the possibility that the physiologic response counteracted the occurrence of any such objective thermal change. Nevertheless, these physiologic reactions may be sufficiently potent to be therapeutically effective. In addition to being used as an effective heating agent, diathermy is also used extensively for the relief of pain and muscle spasm.

<sup>1</sup> SIEMS, L. L.; KOSMAN, A. J.; and OSBORNE, S. L.: A comparative study of short wave and microwave diathermy on blood flow. *Arch. Phys. Med.*, 29:759, 1948.

The *Handbook of Physical Medicine*<sup>2</sup> states that diathermy is indicated in the following conditions:

**Contusions.** The early application of cold by compresses or ice bag will reduce ecchymosis, swelling, pain, tenderness and limitation of motion. After the first 24 hours, infrared radiation and medical diathermy may be applied to increase activity of the circulation.

**Muscle Strains.** These are treated like contusions with regard to the application of cold and heat. For muscle strains, diathermy must be applied for only a short time and at a low intensity for the first treatment, as it may cause an increase in the swelling.

**Myositis Ossificans.** With muscle injuries there is always the possibility of the development of myositis ossificans, which tends to progress unless the affected area is properly treated. The treatment consists primarily in rest and increase of local circulation by various means, especially diathermy.

**Sprains and Dislocations.** There are various degrees of sprains, and treatment varies in direct proportion to the damage done to the soft tissues. Immediate walking may be advised in cases of slight sprain of the ankle, while rest in bed may be indicated in cases of severe sprain.

"A mild sprain of the ankle can be treated satisfactorily by strapping to prevent lateral motion but not plantar and dorsal flexion. The efficacy of this method depends on the efficiency of the strapping. It is thought that plantar and dorsal flexion have a direct effect in promoting return of circulation and prevention of adhesions.

"In the treatment of some sprains and dislocations, fixation by a removable plaster splint and the daily application of heat and massage may be preferred. In sprains or dislocations, ligaments are torn and muscles, blood vessels, nerves, tendons and the synovial membranes of the joint are injured; there is hemorrhage from the torn vessels, swelling and muscle spasm. In

<sup>2</sup> *Handbook of Physical Medicine*: Chicago, A.M.A., 1st Edition, 1945.

flamatory action is noted with heightened local metabolism and elevation of temperature. For immediate treatment, therefore, local applications of cold with rest, proper compression, bandaging and elevation are indicated. After the first 24 to 48 hours, there are local edema and decreased local metabolism. Then the treatment should consist in removal of the splint and bandage followed by the application of external heat or diathermy, and this is usually succeeded by massage and exercise to produce a free flow of blood through the part. Among other important measures following the heating of these parts is the stimulation of circulation by massage and exercise.

**Bursitis.** The first attack of bursitis can usually be relieved by physical therapy in about two weeks. The part should be placed at rest. For acute bursitis, infrared radiation from a luminous source is given for 30 minutes at least twice daily and short wave diathermy is applied for 20 minutes once daily. As the pain diminishes, careful massage and relaxed motion should be employed; later, active exercise is started. Acute subacromial, radiohumeral, olecranon and prepatellar bursitis are treated in this manner. In a few cases, diathermy may aggravate the pain. In these cases it may be necessary to put the patient to bed and apply continuous moist heat.

"For chronic subacromial bursitis, conservative measures, such as rest, infrared irradiation, short wave diathermy, massage and exercise should be tried before operation is considered. In some cases of chronic involvement with severe pain the shoulder should be immobilized in an airplane splint. In this form of bursitis, calcified deposits may form without any apparent cause, are often fragmented and may disappear spontaneously. It is believed that diathermy may aid in the absorption of such deposits. When conservative measures fail, operative removal of the bursa and its calcified deposit is advised.

**Tenosynovitis.** Traumatic tenosynovitis most commonly affects the tendons of the wrist, the achilles tendon and the long head of the biceps. The treatment is to immobilize the joints whose motion causes pain in the tendons. The splint is removed

and short wave diathermy is applied for twenty minutes once daily, followed by radiant heat once or twice daily for 20 minute periods. It may be advisable to use motion in a whirlpool bath to prevent adhesions.

"Rheumatic, gouty and gonorrhreal tenosynovitis are treated in the same manner as the traumatic form. Pyogenic tenosynovitis is a surgical problem and diathermy is not used in its treatment.

**Chronic Arthritis.** This is not a disease of certain joints but rather a systemic illness, in which there may be disturbances of the circulation, general metabolism, gastrointestinal tract and nervous system. The syndrome of chronic arthritis includes the nerve, muscle and joint diseases called neuritis, myositis, fascitis and arthritis, according to the part affected. Local and general applications of heat have perhaps their most extensive varied usage in the treatment of chronic arthritis. In chronic arthritis the circulation in the more narrow vessels, especially at the periphery, is usually diminished. The involved area may be cold and clammy, but they may also present rubor, dolor and calor. In any event, local heat may prove of great value, as many systemic applications, because of the alteration and improvement in the circulation, brought about. Great care should be exercised in the application of heat in cases of hypertrophic arthritis, since heat may constitute a form of trauma which aggravates the conditions already present. When indicated, however, local application of heat should be made from two to four times a day in the patient's room to produce an adequate increase in circulation, and, if medical diathermy is used, it may be supplemented with the former treatment. When medical diathermy is used for chronic arthritis it should be used for a short period with low intensity for the first few doses, because sometimes it causes an aggravation of the local symptoms. Clinical benefit, however, has been observed so often from diathermy that one should always give it a trial.

**Myositis and Myofascitis.** These conditions are inflammations of the muscles characterized by pain on motion, spasm and tenderness on pressure. When the inflammation involves the

lumbar muscles, it is known as lumbago, the intercostal spaces, pleurodynia, and the neck muscles, torticollis. In the local treatment of acute forms, rest and the application of heat are recommended. This heat may be applied by hot compresses, continuous moist heat, infrared radiation from a luminous source or medical diathermy.

**Fibrositis.** This has been defined as a swelling and proliferation of the white fibrous tissue anywhere in the body in response to injury or very toxic infection, with a secondary effect of pressure on arterioles and nerve filaments. Many American clinicians have been loath to recognize fibrositis because its morphologic lesions are ill defined and its symptoms subjective. Those who do recognize it by its nodules in the muscles classify most forms of muscular rheumatism as fibrositis and treat the condition with deep massage. Heat, massage and exercise are used as adjuncts in the treatment, and diathermy may be used as one of the methods of giving heat.

**Fractures.** The principles of fracture treatment are restoration of anatomic form, maintenance of alignment and fixation of the fracture during the period of union, and maintenance and development of function. Heat, massage and mobilization are important physical therapy measures, the object of which is to increase the activity of the circulation, to prevent adhesions in muscles and joints, to prevent muscular atrophy and later to increase muscle strength. The heat, of which one method of production is medical diathermy, is used mainly as an adjunct to massage and exercise.

**Genito-Urinary Conditions.** Medical diathermy is used by a few clinicians as one of the methods of applying heat for the treatment of epidymitis and prostatitis.

**Pelvic Infections.** Some gynecologists use medical diathermy as one of the methods of applying heat in cases of pelvic infection, although most gynecologists believe that a low degree of heat usually suffices.

**Respiratory Diseases.** The chest compress is used by some clinicians to apply heat in the treatment of bronchitis. If the

patient is in the hospital, it is believed that medical diathermy is more effective and easier to apply. With bronchitis, this method relieves the pain and soreness in the chest, reduces the viscosity of the secretions and thus makes expectoration easier; it also relieves the coughing.

"It has been observed that, in the management of pneumonia, medical diathermy does seem to be of definite benefit in reducing the severity of thoracic pain. This symptomatic relief is important. The main factors concerned in the production of anoxemia are the passage of blood through the unaerated portion of the lung and shallow breathing. The shallow breathing may be due to pleuritic pain restricting the respiratory excursions. The relief of this pain by diathermy increases the respiratory excursions and this may be the explanation for the decrease in cyanosis that is usually noticed. There is no evidence that medical diathermy has a specific action on the pneumonic process.

**Gastrointestinal Diseases.** For such conditions as acute enteritis, spastic colitis and simple catarrhal jaundice, abdominal warmth is suggested as an aid in treatment. An electric heating pad or a hot water bag kept on the abdomen for hours at a time is useful therapeutically. Infrared irradiation is a convenient way of applying heat; diathermy, if mild and properly applied, is also of benefit.

**Inflammation of the Peripheral Nerves.** With the various forms of neuritis, radiculitis and neuralgia, applications of heat may allay the inflammation and the pain. For deep penetration of heat into the tissues, medical diathermy may be used as a method of applying heat as an adjunct in general treatment. In the case of acute neuritis or acute radiculitis, it is believed that the first two treatments should be given at half the patient's tolerance for about ten minutes to see whether there is any aggravation of the symptoms.

**Acute and Chronic Sinusitis.** Infrared irradiation and medical diathermy are useful adjuncts to other treatment after adequate drainage has been established. Medical diathermy is of

value as an aid in the relief of pain; the frontal and maxillary sinuses are the ones most suitable for treatment.

**"Eye Diseases.** The indications for medical diathermy are by no means well established. It is believed that this treatment may be used to relieve pain from chronic keratitis, neuralgia, herpes zoster and iritis.

**"Suppurative Processes.** Short wave diathermy has been advocated in the treatment of suppurative lesions with external drainage and doubtless will be of aid in this treatment. However, sufficient comparative study is not available to determine whether short wave diathermy is more effective than the simpler forms of heating."

## VII

## SURGICAL DIATHERMY

**I**N CONSIDERING this most important subject, it is believed that some discussion of the nomenclature used in this field will aid in a more intelligent understanding of its principles and uses. Surgery, accomplished by the use of a high frequency electric current, is commonly spoken of as *electrosurgery*, and is divided into three different classifications, which we shall speak of as *electrodesiccation*, *electrocoagulation*, and *electrocutting*.

**Electrodesiccation (Fulguration).** Electrodesiccation may be defined as the dehydration and shrinkage of superficial tissue by damped high frequency currents. Application of the current to the tissue to be destroyed is made by means of a needle-point electrode held in contact or at a slight sparking distance. A relatively low intensity of current is usually employed. Drying and shrinkage of the tissue treated results, due to the evaporation of the water content of the tissue cells. The dry mass that remains may be curetted away or left in place to scale or slough off.

Careful studies have shown that following electrodesiccation tissue cells are shrunken and shriveled, with their nuclei condensed and elongated. In electrodesiccation the tissue cells retain a suggestion of cell outline. Briefly, the result is a mummification necrosis. Since, with this type of cell destruction, there is little degenerative change and but a small amount of disintegrated material, there is only a small amount of fibrous tissue formed. On this basis are explained the excellent cosmetic results obtained with electrodesiccation.

According to Kelly and Ward electrodesiccation is used chiefly for lesser growths with small blood vessels, such as warts, moles, corns, and similar skin blemishes.

**Electrocoagulation.** Electrocoagulation is the coagulation of tissue by damped high frequency currents. Application of current is made by means of either a sharp or blunt pointed elec-

trode inserted into the tissue to be destroyed, with a large dispersive electrode connected to the other terminal of the high frequency generator; or by means of duoterminal active electrode, consisting of two active electrode tips or surfaces to be inserted into or applied to the tissue to be coagulated, or of a specially constructed clamp electrode with two active surfaces between which the tissue to be coagulated is clamped.

In the case of the mono-terminal technic, coagulation takes place around the active electrode and in diminishing degree as distance from the active electrode increases. The depth and extent of coagulation obtained varies with the strength of the current employed, the time of application, and the size or type of electrode.

In the case of the duoterminal technic, coagulation takes place between the two electrodes, both of which, since they are of the same size, are active electrodes. Obviously better control of the depth and extent of coagulation is made possible with this latter technic. To do careful and satisfactory electrocoagulation of tissue, it is of course necessary to be able to control by fine graduation the intensity of the high frequency current.

Following electrocoagulation, there appears, to a varying depth and extent, a change in color of the tissue to grayish-white. Histologically the cell outline is completely lost, and the coagulated tissues become fused into a structureless, homogeneous mass having an appearance not unlike that of hyalinization. Briefly, the cells have been boiled by a high temperature in their own fluid. The destroyed tissue sloughs with remarkably little scar formation—much less than when the cautery is employed. By cautery is meant the application of a heated electrode to tissue for the purpose of producing destruction. The destruction produced by cautery is greatest near the electrode, being chiefly superficial carbonization, which results in more extensive scar formation.

**Electrocutting or Electrosection.** Electrosection may be defined as the cutting of tissue by means of an undamped or slightly damped high frequency current. The cutting current is

applied by means of a needle, a knife, or a loop electrode, with a large dispersive electrode connected to the other terminal of the high frequency generator. The energized active electrode is brought into contact with the tissue to be severed and an arc is established. As the electrode is moved, the tissue separates immediately in advance of the arc, due in all likelihood to an ex-



FIGURE 59. Electrocoagulation and desiccation electrodes.

plosion of cells from the pressure developed by the steam generated within them. Coagulation of tissue to varying depths takes place on each side of the incision. The degree of coagulation depends on the technic employed in making the incision. If too much coagulation of tissue takes place, healing of the incision will not occur by primary intention. If, however, only a very thin layer of tissue on each side of the incision is destroyed, resulting in no greater quantity of necrotic cells than can be absorbed, healing will take place by primary intention.

**Technic of Electrodesiccation.** A pointed electrode, held in a special handle (Figure 59) is connected to one of the high volt-

age terminals of a conventional diathermy generator. A footswitch is connected to the generator so that the operator can control the current application to the patient by means of his foot. Current intensity is gauged by opening the spark gaps and then, while stepping on the footswitch, by holding the active needle electrode close to a coin. The spark gaps are adjusted to give a short arc if light current is required, and a longer arc if heavy current is needed. In this manner a preliminary adjustment of current is made. During actual application, however, the current intensity may need to be increased or decreased.

The active electrode is approximated to the pathologic tissue and the footswitch closed. The electrode does not enter the tissue, although in some cases it may make actual contact. The active electrode is confined strictly to the area to be desiccated. After electrodesiccation a dry mass remains, which may be curetted away or left in place to slough away. Patients must be warned not to interfere with the eschar or scab which forms.

To obtain sufficient current with some machines it may be necessary to ground the second terminal of the generator to a suitable ground such as a water pipe. Grounding to the chassis of the generator may suffice in some cases.

**Technic of Electrocoagulation.** 1. *By a Single Active Electrode.* Electrocoagulation differs from electrodesiccation in type and degree. In electrocoagulation greater destruction, both as to depth and area, is produced. The active electrode is introduced directly into the tissues, and connected to one terminal of the generator. The other terminal is attached to a dispersive electrode, a large metal plate, which is applied securely to some area of the body. The current employed is of high amperage and low voltage, such current as is used for direct conventional medical diathermy application. The generator is operated in the same manner as for desiccation and with a footswitch to control current flow.

It has been customary to short circuit the two diathermy terminals by means of the connecting cords, and then open the spark gaps until a given (short circuit) current is registered on

the milliammeter, the given current on short circuit being that which experience has taught corresponds to the required current for the desired coagulation. The active and dispersive electrodes are then connected to the diathermy terminals which were shorted, and the operation started. Further adjustment of current intensity, if necessary, can then be secured by either opening or closing the spark gaps. At the termination of the operation, the terminals can be again short circuited, and the me-

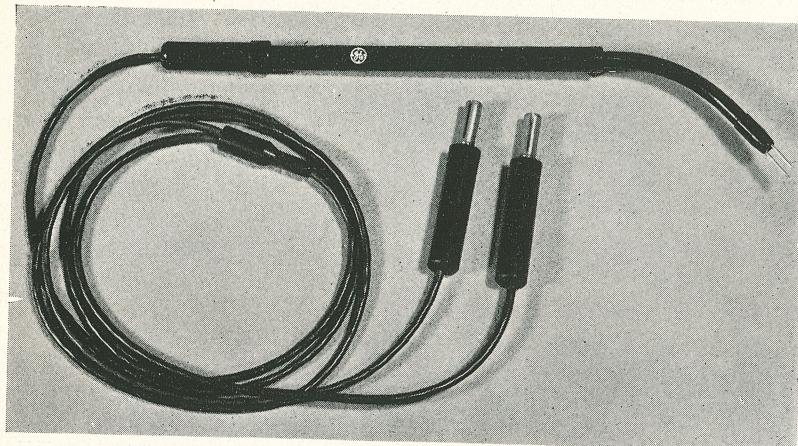


FIGURE 60. Jaros Tonsil Electrode.

ter read to ascertain the actual short circuit current that was used, such data enabling the operator to duplicate his technic. It must be realized that the short circuit current is not necessarily the current that flows during the application. It serves merely as a means of duplicating generator settings.

2. *By a Duo-Terminal Electrode.* A more recent development in the technic of electrocoagulation employs duoterminal electrodes, such as the *Jaros Tonsil Electrode*, the *Kimble-Jaros Cervical Electrode*, and the *Jaros Turbinate Electrode* (Figures 60, 61 and 62). The two active applicators constituting the electrode are inserted into or applied to the tissues. Coagulation occurs in the zone between the two applicators. By re-inserting

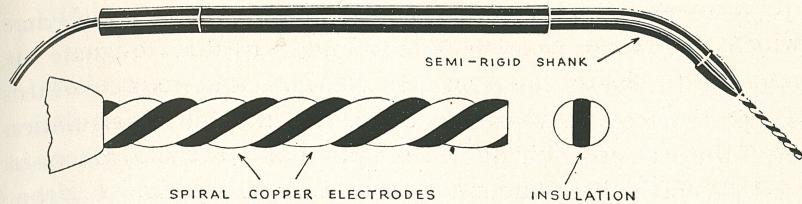


FIGURE 61. Kimble-Jaros Cervical Electrode.

the electrodes or by moving the electrodes while maintaining contact with the tissues, greater areas of coagulation can be obtained. With such electrodes no dispersive electrode is required.

Another type of duo-terminal electrode is the so-called clamp type, such as the *Bierman Hemorrhoidal Electrode* (Figure 63). Such an electrode consists of a suitable clamp with jaws of mutually insulated metallic plates. The tissue to be coagulated is clamped between these two active electrodes.

**Technic of Electrosection or Electrocutting.** There seems to be no general agreement on the term to be used to designate the severing of tissue by means of high frequency currents. The term *Electrosurgery* includes all surgical technics with high fre-

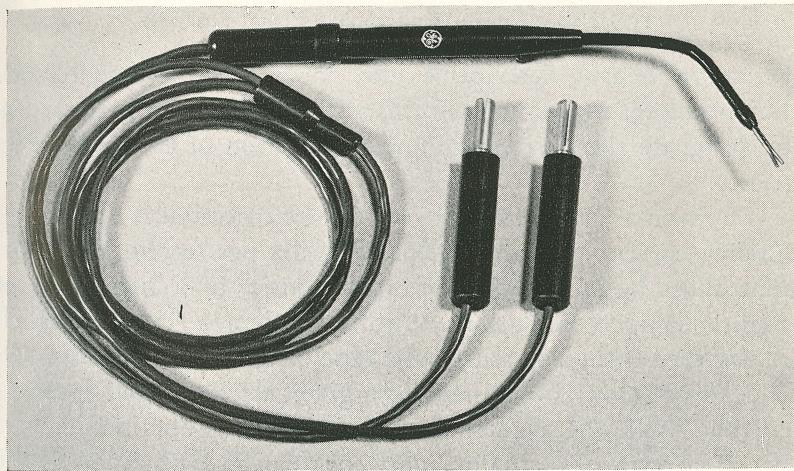


FIGURE 62. Jaros Turbinate Electrode.

quency currents—desiccation, coagulation, and cutting. Hence we believe that some other term should be used to designate the cutting of tissue—some term that would be as descriptive of this surgical procedure as electrodesiccation and electrocoagulation are for the desiccation and the coagulation of tissue by electrical currents of high frequency. Krusen suggests the term *Endosection*, as indicative of the sectioning or cutting of tissues from within. We believe, however, that the term *Electrosection* would

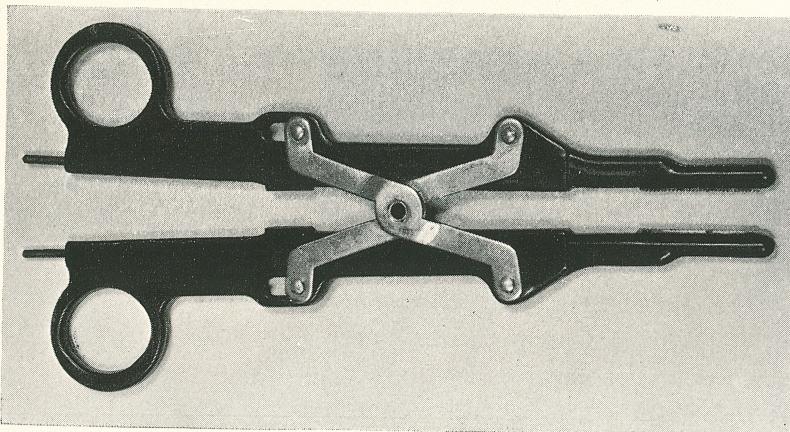


FIGURE 63. Bierman Hemorrhoidal Clamp Electrode.

be more nearly descriptive and more readily understood. Furthermore, the term conforms with the terms in general use to designate the desiccation and coagulation of tissues by electricity.

The type of current employed for electrosection is a high frequency current of about 3,000,000 cycles per second. The current must be undamped, or must consist of a succession of slightly damped oscillations. With the undamped current, which is obtained from a vacuum tube type of oscillator, minimal lateral coagulation is obtained for a given electrode and speed of cutting. With the slightly damped current, as obtained from a spark gap type of oscillator, more coagulation is obtained. If the damping of the oscillations is too great, no cutting will be ob-

tained. Such a highly damped current is used for the other surgical procedures, namely, coagulation and desiccation.

The field of electrosection is extensive. No attempt will be made in this book to describe the technics to be employed, for such applications of electricity are outside the scope of this work. For information on the subject it is suggested that a work such as that by Kelley and Ward be consulted.

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*This Book*

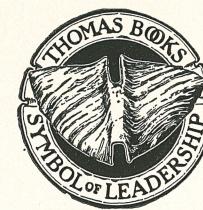
# DIATHERMY

The Use of High Frequency  
Currents

*By*

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